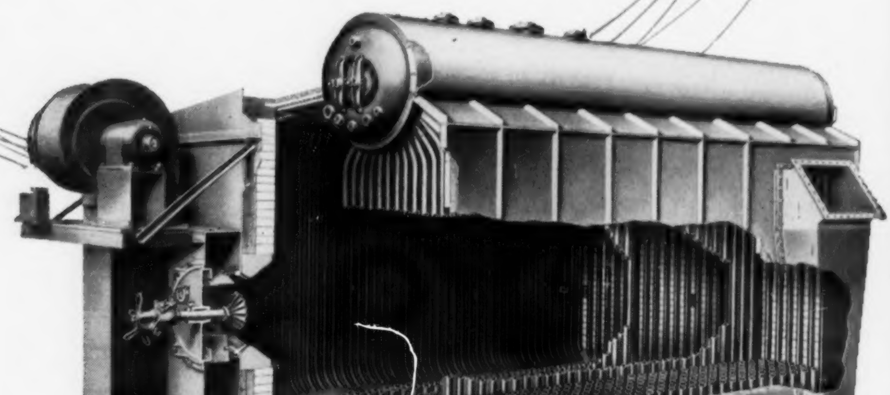
COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

May 1954

Cities Service Co. by Fritz Henle

Industrial Steam Generating Plant



COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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Editorials

A Rosy Future

The state of health of the national economy is properly a matter of concern to each and all of us. When the economy is weathering a period of inventory readjustment or realignment as is the case today general interest in business predictions runs strong. As a result it seems that each and every segment of the economy has gone on record with their beliefs and views.

Now along comes a prediction on the electric power future by Tomlinson Fort, vice president in charge of the apparatus division of Westinghouse Electric Corp. Some of the statistics he gave in a talk before the 20th annual sales conference of the Edison Electric Institute are well worth passing on.

The future rate of growth for the electric utility industry, for example, in the opinion of Mr. Fort, will be 7.4 per cent annually as compared to 3.4 per cent for our overall economy! That's a growth rate of more than double the general average.

A very large part of the support for this healthy growth rate is the conviction that industrial power requirements, alone, will top 400 billion kwhrs by 1963 from its present level of 257 billion kwhrs with a rise from $9^1/_2$ to 15 kwhrs per man-hour of production. Mr. Fort attributes this boost in electric energy per man-hour to two key factors: (1) the need of industry "to free itself from today's web of rising labor and material costs" by applying techniques of electrical modernization to increase output per man-hour and unit of plant area, (2) the fact that productive man-hours in ten years will be no greater than today because of the trend towards a shorter work week, more holidays, longer vacations, and earlier retirements.

The nation's chemical, steel and non ferrous metals groups proved the biggest industrial customers for electric energy, accounting for 41 per cent of the total kwhrs used by industry last year. Next came petroleum, natural gas and pulp and paper manufacture with 16 per cent of total consumption. The Atomic Energy Commission, textile, stone, glass, and clay industries accounted for 14 per cent, and the rubber and coal industries reached an aggregate of four per cent. Metalworking industries and other miscellaneous groups consumed the balance of industrial electric power.

Mr. Fort saw several industries as certain to increase their electric energy demands sharply within the next ten years. Metalworking was one he termed as possessing "tremendous kwhr potentials" and he expected it to double its power consumption by 1958. The present growth of the chemical industry will produce a probable demand for 61 billion kwhrs by 1963 which will just about equal the steel industry's needs of the same period.

The air conditioning market is truly a phenomenal one. From an 8.9 million kwhr energy demand in 1950 this industry jumped to 13.8 billions in 1953. Mr. Fort looked for power consumption in this field to reach 45 billion kwhrs within nine years. There are still more encouraging signs. A recent survey of electrical utilities that Mr. Fort's concern carried out indicated lighting sales potentials that were incredibly large.

The above certainly points to some very active years ahead for the power industry as a whole. Under the stimulus of such a vigorous load growth power plant design will undergo repeated changes. Elsewhere in this issue, p. 34, in a report on the Gallatin plant of the TVA the authors comment on the remarkable advancement in the art of designing and manufacturing steam plant equipment within the four-year period marking TVA's change from a primarily hydro system to one where steam predominates. The next ten years will unquestionably see further advances.

Fuel Advisory Services

Promotion of fuel economy is carried on in many ways in countries throughout the world. Trade associations sponsored by fuel producers, manufacturers of fuel-burning equipment, technical societies concerned with power plant operation and government agencies are among the groups that concern themselves with one or more phases of the efficiency of thermal plant performance.

An interesting article in the April issue of the British publication, *Engineering and Boiler House Review*, tells of European experience with fuel advisory services. Compulsory control over thermal plants is in force in France and Italy, and these countries have officially sponsored fuel advisory agencies. These are staffed by technical experts who make inspections at least once every two years and set up standards of construction, testing and operation. Somewhat similar government services are provided in Great Britain and Western Germany, although the element of compulsion is absent.

In Denmark a voluntary service, Danish Fuel Control Association, has been set up by boiler plant owners. This group has a staff of combustion engineers who make unannounced annual inspections of member plants. It also provides an evaluation service which works out the relationship between consumption and mean outdoor temperature on a weekly basis.

Private initiative is the basis of services in Holland and Belgium. In the former, the state mines advise customers on choice of fuels and appropriate methods of obtaining maximum thermal efficiency, and there are other services sponsored by industrial and consulting engineering organizations. Belgium has always relied on the policy of educating the public to realize the importance of fuel economy. During the fuel shortage of 1947 some legislation was proposed for state inspection service but was not adopted.

It is to be expected that fuel advisory services will be expanded in other European countries. The Coal Committee of the Economic Commission for Europe has recommended that producers, consumers, manufacturers and distributors should be participants in both existing and future services. Increased cooperation with professional groups and technical associations may also be expected. Future developments of these European fuel advisory services will be watched closely.

*The Gallatin Steam Plant of the Tennessee Valley Authority**

By C. E. BLEE† and H. J. PETERSON‡

Tennessee Valley Authority, Knoxville, Tennessee

In addition to describing features of the principal equipment of this plant, in which will be installed two 250-mw units scheduled to begin operation late in 1955, the authors discuss design trends in steam plants of the Authority.

THE power system of the Tennessee Valley Authority is undergoing a change from an almost entirely hydro system to one in which steam-electric power will predominate. This is the history of practically all the large, growing utility systems which initially were supplied primarily from hydro sources. There is presumably in each case some combination of hydro and steam which would produce the most economical power supply. What this relationship is depends on the conditions of hydro and steam power supply available in a particular system together with the load characteristics. The question is really academic since, to be realistic, it comes down to a matter of meeting the load demands in a practicable manner. In the case of TVA the impact of unprecedented loads, spearheaded by the requirements of the Atomic Energy Commission and other defense agencies, left no choice but to go ahead with a program of steam plant construction which has developed into an undertaking of sizable proportions.

The chart (Fig. 1) shows the supply and demand on the TVA power system going back to January 1, 1944. The load is given in terms of hourly peak in kilowatts. For the years up to January 1, 1954, this is the load as experienced. For the future years shown, the expected load demands are based on an analysis of the past and present loads. The AEC load is a very considerable factor in the present load and is reflected in the estimated future load to the extent that it is covered by contracts. The load demands of the municipalities and cooperatives which are supplied wholesale by TVA are showing a sustained heavy rate of growth.

The installed generating capacity on the system in terms of name plate rating was 2,639,000 kw as of January 1, 1949; today, five years later, it is 5,689,000 kw; at the end of calendar year 1956, eight years later, it will be 9,935,000 kw, approaching four times the 1949 capacity. At the start of this present program of steam plant construction in 1949, there was only 437,000 kw of steam-electric generating capacity in the system, amounting to 16 per cent of the total installed capacity. Today, the steam amounts to 2,237,000 kw or 39 per cent; at the end of 1956, the steam will amount to 6,287,000 kw, representing 63 per cent of the system's generating capacity. While the additions of generating capacity in the more recent years have been largely in steam-electric units, hydro possibilities have not been overlooked. During the five years from 1949 to date, hydroelectric generating units with a combined capacity of 1,250,000 kw have been added to the system. Hydro will continue to play its part in the development of the system but the available sites remaining will accommodate only relatively small installations and it would be utterly impossible to keep pace with the load demands by building such stations.

Design Trends

In the brief period of time covered by this program of steam plant construction, there has been a remarkable advancement in the art of designing and manufacturing steam plant equipment. This is reflected in the progressively changing characteristics of the units installed on the TVA system. These units are listed chronologically in Table 1. A corollary of this change in the characteristics of the units is that although started less than a year apart, no two stations are duplicates, a fact which has not lessened the heavy design load.

It may be noted from the data given in Table 1 that in the approximately four years covered by this table, the maximum guaranteed capabilities increased by stages from 125 mw to 150 mw to 200 mw and finally to 250 mw at Gallatin. In this same period the throttle temperatures rose from 1000 F to 1050 F, with 1000 F and 1050 F reheat in the later stages. The throttle pressure kept pace by increasing from 1450 psig to 1800 psig and finally to 2000 psig at Gallatin. The trend of the net plant heat rate, of course, followed the more efficient heat cycles by reducing from 10,086 Btu per kwhr at Johnsonville to 9216 Btu per kwhr at Gallatin, a gain of 8.6 per cent.

The above illustrates that the Authority is taking advantage of what might be called the conservative advances in the art of generating steam-electric power. The above stations will be among the most efficient in the world. Capacitywise the TVA has taken its place as one of the leaders because of the lesser reliability risk involved in increasing capacity. It is true that there are other stations being designed with higher temperatures and much higher pressures, but TVA has preferred to let those units get a trial by performance before accepting their more extreme heat cycles.

Selection of the Gallatin Unit

With its strategic location near the center of the system and with the site features as to topography,

† Chief Engineer.
‡ Head Mechanical Engineer.

* Presented before the American Power Conference, sponsored by the Illinois Institute of Technology, March 24–26, 1954.

TABLE 1—DESIGN TREND OF TVA STEAM PLANTS

Plant	Auth. No. Units	Starting Date, First Unit	NPHR,* Btu/kwhr	Unit Guaranteed Capability, mw	Temperature, °F	Pressure, Psig
Johnsonville	1–4	Oct. 1951	10,086†	125	1000	1450
Widows Creek	1–4	June 1952	9,972	125	1000	1450
Johnsonville	5–6	Nov. 1952	10,015	125	1000	1450
Shawnee	1–10	Apr. 1953	9,303	150	1000/1000	1800
Kingston	1–4	Feb. 1954	9,271	150	1000/1000	1800
Widows Creek	5–6	May 1954	9,296	125	1000/1000	1800
Kingston	5–9	Sept. 1954	9,191	200	1050/1050	1800
Colbert	1–4	Oct. 1954	9,201	200	1050/1050	1800
John Sevier	1–3	June 1955	9,170	200	1050/1050	1800
Gallatin	1–2	Nov. 1955	9,216	250	1050/1050	2000

* Calculated NPHR at maximum guaranteed capability of the turbine and $1^1/_2$-in. Hg back pressure, using manufacturer's guarantees.

† Actual NPHR for fiscal year 1952 as reported to Federal Power Commission.

Tabulated data, above, pictures rapid progress of steam design with ever lower heat rates, higher capabilities

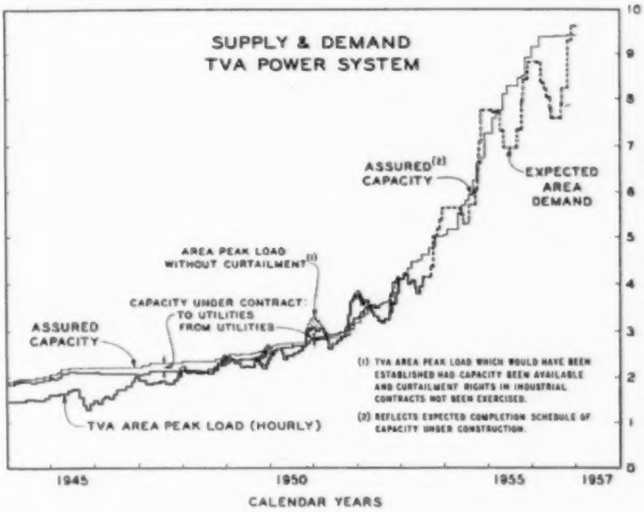

Fig. 1—Supply and demand on TVA power system, right

foundations, cooling water, coal supply and transportation being favorable, the Gallatin plant was envisioned as ultimately being a very large capacity generating station and one which would justify large units. (See Fig. 2.)

Table 1 indicates that the Gallatin plant will have a slightly higher heat rate than will the John Sevier plant with its 200,000-kw units. The difference is due to various factors, such as differences in the coal, difference in manufacturer's guaranteed boiler efficiencies and, because, while each turbine has the same exhaust annulus area, more steam is exhausted from the larger unit resulting in a slightly higher back pressure. At the design back pressure of 2-in. Hg this difference is narrowed to 27 Btu per kwhr (0.29 per cent). Temperature conditions of the cooling water are such that the units at Gallatin will be operating approximately one-half of the time above $1^1/_2$-in. Hg back pressure and one-half of the time below. The selection of the units with a slightly lower efficiency was justified because of the extra 50,000 kw per unit obtained and because of the lower operating expense and building cost per kw of capacity.

Layout and General Design Features

The unit system of one boiler per turbine was employed. A high availability factor is expected from the boiler so there was no need of splitting the boiler load in view of the excessive cost for so doing. No cross-connections are to be installed between units. These were installed at the Watts Bar plant but they have never been operated.

As will be noted from the cross section of the plant, Fig. 3, the operating functions are concentrated on two main levels which are the basement level and the grade level.

Partial outdoor type of construction is employed in that the dust collectors, induced-draft fans, and ductwork are all outside the powerhouse enclosure. A comprehensive study was made to determine the savings of an outdoor type of plant over the partial outdoor type used at Gallatin. The saving indicated was not considered sufficient to overcome the operating objections to an outdoor plant.

Because of the large gas flow from the Gallatin boilers it was found advisable, because of physical limitations, to use three air preheaters per boiler. A detailed study was made whether or not to use three forced- and three induced-draft fans per boiler or to use two of each together with plenum chambers. It was found that the latter scheme was somewhat cheaper. However, the former scheme of three of each fan per unit was finally adopted for the following reasons:

1. Smaller fans. The larger fans would require excessively large handling equipment for maintenance.
2. Ten large isolating dampers are eliminated by the three-fan scheme.
3. One fan lost in a three-fan system means a loss of about 20 per cent of unit capacity, whereas with a two-fan system this loss would be about 40 per cent.
4. Simpler and smaller duct arrangement.

An interesting feature of the condenser circulating water system is the water passages which run from the pumps at the river's edge to the condensers and out again to the river. These passages are approximately 72 ft below grade and lie in solid rock. There is one 8-ft diameter concrete-lined tunnel to and from each unit and the total length per unit is approximately 1100 ft. The considerable excavation and backfill involved if these passages had been excavated from the surface instead of tunneled was eliminated at a very appreciable savings in cost.

Another interesting development occurred in the layout of the large units. Heretofore, all turbines in previous plants were placed with their longitudinal axes at right angles to the length of the powerhouse. In the Gallatin plant it was found that the boiler width controlled the spacing of the units even when the turbines were placed end to end. Consequently, the machines are laid out in this manner, which permits a much narrower turbine room; see Fig. 3. This reduction is 29 feet from the 200-mw units at John Sevier to the 250-mw units at Gallatin. The savings in building and crane costs are obvious.

Principal Equipment

Turbogenerators

The Gallatin turbines have a guaranteed capability of 250 mw operating under initial steam conditions of 2000 psig and 1050 F, reheat to 1050 F, exhausting to a

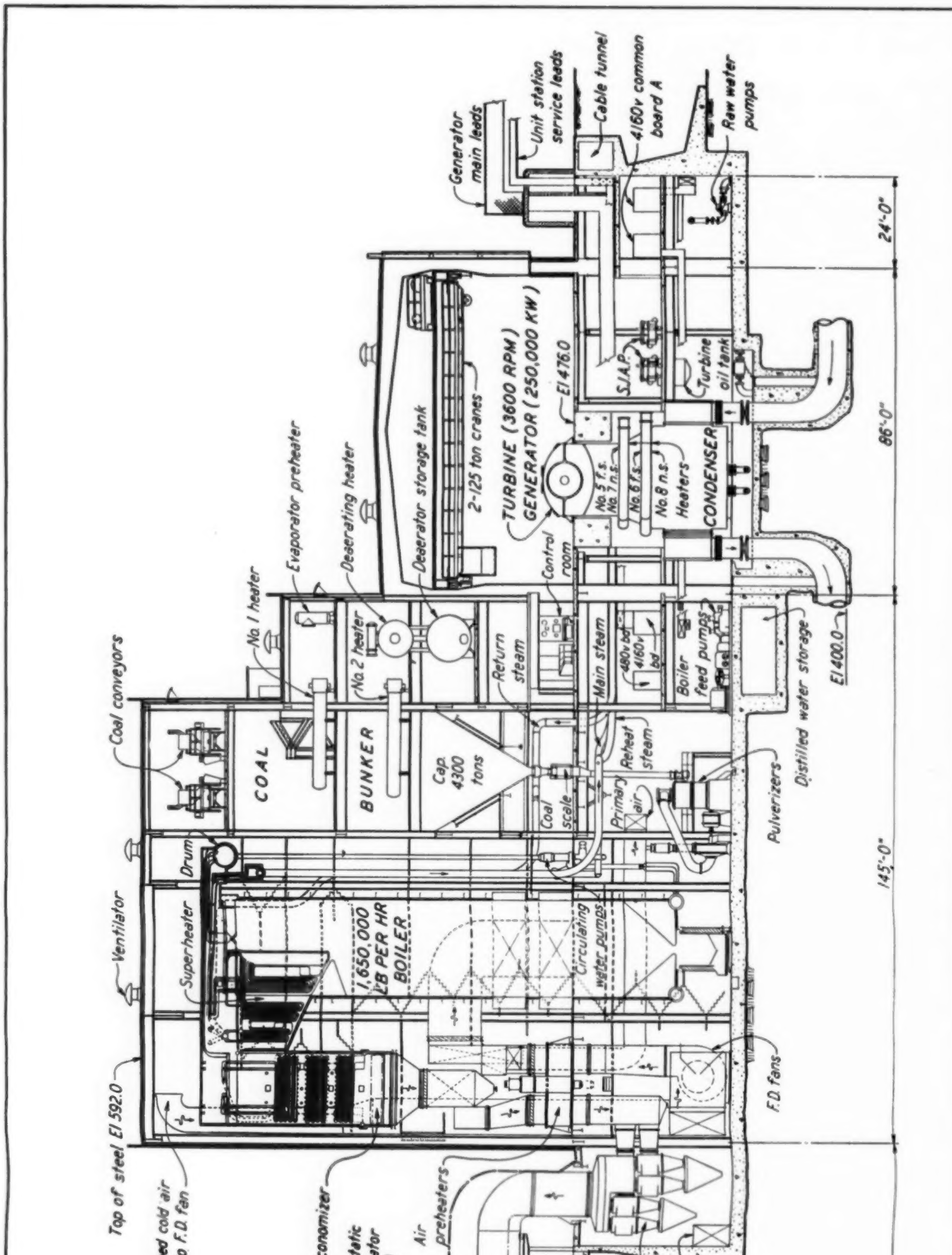

Fig. 3—Cross-section of Gallatin Steam Plant

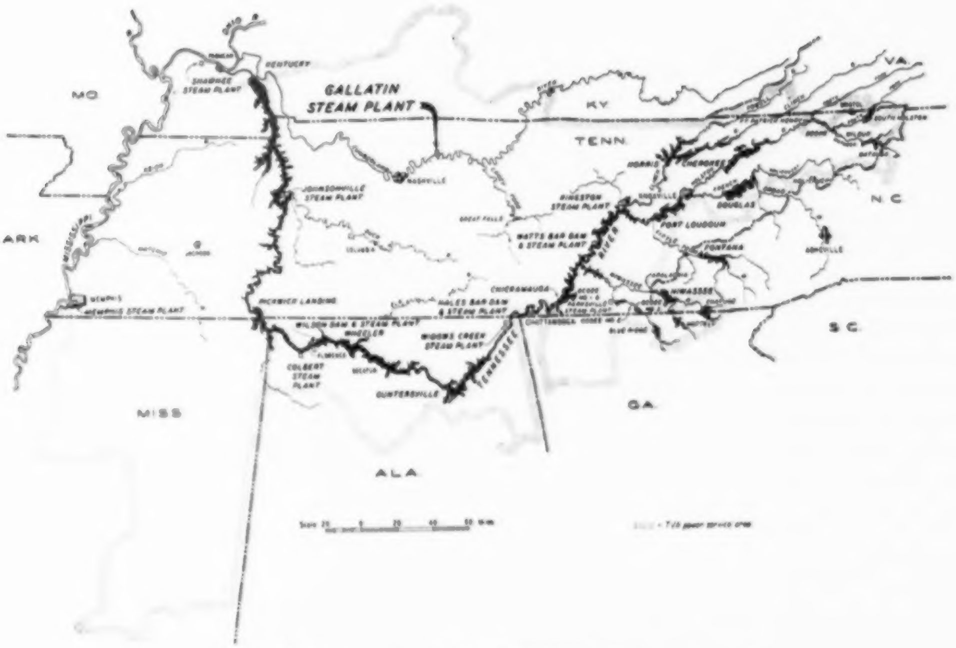

Fig. 2—Location of the Gallatin Steam Plant

back pressure of $2^1/_2$ in. Hg absolute. They are single-shaft, tandem-compound, triple-flow units.

The generators have a continuous capability of 250 mw or 277.8 mva at 0.9 power factor, 30-psig hydrogen, 24 kv. At 45-psig hydrogen these generators will have a maximum capability of 287,500 kw or 319,445 kva at 0.9 power factor. At the time of installation these units will be the largest in the world.

The 250-mw rating was chosen after full discussion with the various turbine manufacturers. It was finally decided to install units of this rating, first, because the manufacturers with their design experience on units of 200-mw capacity felt no hesitancy in going to this next higher step. Then, too, the obvious advantages of less operating labor and less building space per kw of these larger units carried a great deal of weight. Because of the large installed capacity of the TVA connected system this rating imposed no regulating restrictions. These units are of a smaller proportionate size to the TVA system than the 60-mw Watts Bar units were when they were installed in 1942.

The temperature and pressure of these units also was given considerable study. Eleven hundred degrees was rejected because of the limited operating experience with this temperature. The use of ferritic steels is possible with 1050-F temperatures while austenitic steels are required for 1100 F and above. Pressures above 2000 psig were rejected for the lack of operating experience above this figure and because of the small gain obtained at a considerable increase in cost.

Cross-compound units were considered since they have extra capability and better efficiencies in the lower back pressure ranges. However, our studies indicated that this advantage was outweighed by their higher installed cost. Several companies are now offering a close coupled cross-compound unit which compares favorably with a single-shaft unit in installed cost and heat rate for these larger capacities; such units will be studied for any future plants which the Authority may build.

In common with practically all the larger units now being installed in this country the reheat cycle was chosen. The $4^1/_2$ to 5 per cent gain in fuel economy, together with the smaller condensers, feed pumps, etc., required for the reheat cycle makes it very attractive. With fuel costs for the Authority at 18 to 20 cents per million Btu the second reheat cycle is not economical and was not considered. There was some question whether to use 1000 F or 1050 F for the reheat temperature. Analytical studies made on a previous plant (Colbert) indicated a substantial return on the additional investment required for the 1050 F temperature, so it was selected for Gallatin.

The greatest limitation on generator size is the problem of removing the heat generated by current flowing through the conductors. At Gallatin a step forward is being taken in this direction by the application of inner-cooling to both the stator *and* the rotor windings. This type of cooling makes possible a much smaller generator for the same output or, conversely, a much larger output for the same generator frame. At Gallatin this is emphasized dramatically by the fact that the generator is 110 inches less in length and 263,000 pounds less in weight than a comparable conventionally cooled generator of equal rating. The savings in building space, crane capacity and foundations are apparent.

As a measure of progress in generator cooling the Authority has advanced from air cooling at Watts Bar to 0.5-psig hydrogen conventional cooling at Johnsonville to 30-psig hydrogen inner cooling at Gallatin. Liquid cooling with its higher heat removal potentialities will be investigated for future large units which the Authority may install.

Steam Generators

The Gallatin steam generators are twin-furnace, controlled-circulation, tangentially fired units similar to those previously purchased for the last five units at Kingston and the three at John Sevier. However, in order to drive the 250-mw turbines the ratings have been stepped up to a continuous flow of 1,650,000 lb per hr at 2035 psig at the superheater outlet, with total steam temperature of 1053 F for both superheater and reheater.

Provision is made for a four-hour peak load of 1,780,000 lb per hr.

The principal feature of the twin-furnace design is that the entire reheater is installed in one of the furnaces and the finishing-off section of the superheater in the other furnace. This permits control of the temperatures in each furnace separately. Control of exit steam temperatures is by tangential burners, with spraying used for emergency conditions only.

A further reason for selecting the twin-furnace design for a unit having a boiler input of 2380 million Btu per hour, such as at Gallatin, is that the structural supports and the furnace accessibility of a single furnace design become a problem. With separated furnaces it was possible to install a center column between them, thereby decreasing greatly the size of the supporting girder and other structural members. Then, too, the retractable soot blowers were reaching lengths where their use was becoming uneconomical.

The many advantages of controlled circulation are outlined by W. H. Armacost[1] in his recent paper on that subject. The paper by Crossan and Ryan[2] confirmed that although they experienced some starting-up difficulties these advantages had been realized at Chesterfield. We also expect some starting-up and operating difficulties with the twin-furnace, controlled-circulation installations but believe they are not insurmountable and are far outweighed by the advantages gained.

The furnaces are of the dry-bottom type principally because we did not want to be limited to low ash-fusion coal. With the huge quantities of coal that the Authority burns on its system it is necessary to be prepared to use any kind of coal that might be available. As an aid in this direction furnace heat release and gas velocities are kept to a minimum and the water-cooled heat absorbing area is high.

Regenerative-type air preheaters are used and the design exit gas temperature is 286 F, including leakage. Lower temperatures were considered but rejected because of the danger of plugging in the preheater. Space is provided in the preheater casing for additional elements to lower this exit gas temperature if it should prove feasible in the future.

Automatic sequential steam soot blowers are used. Air was considered for a previous plant, but was rejected in favor of steam for cost and operating reasons. Electric motor operators are used for the blowers because they are believed to be more reliable than air motors.

Condenser and Circulating Water System

The site of the plant on the Cumberland River assures an ample supply of cooling water. For this reason, conventional single-pass, divided-water-box condensers will be installed. A pumping station is being built on the river bank with two vertical mixed-flow pumps per unit. Both pumps are necessary to pump enough cooling water to maintain design vacuum in the unit at rated load and at usual summer river temperatures. However, one pump operating alone will pump sufficient water to permit maximum output of the unit at 3-in Hg back pressure with maximum river temperature.

Heaters

An economic study indicated that eight feedwater heaters should be used. Four of these are low-pressure heaters through which two condensate pumps (three provided per unit) pump the water to the deaerator. The boiler feed pumps pump the water from the deaerator storage tank through the three high-pressure heaters to the boiler.

The Authority prefers closed heaters over open heaters because of the simpler pumping and piping arrangement. Because of the large volume involved, consideration was given to splitting the flow through the heaters into two parallel systems. However, the various heater manufacturers gave assurance that they could design the high-pressure heaters to handle the total flow in single heaters in series, so this method was adopted.

Boiler Feed Pumps

The large flows also prompted consideration of four feed pumps per unit. This was discarded in favor of three pumps per unit (one being a spare) because of the complexity of the controls and piping required for four pumps. The feed pumps have hydraulic couplings with scoop control for regulating speed and flow. The economy of the hydraulic couplings was established at Johnsonville. The scoop is regulated by a standard three-element control (feedwater flow, steam flow and drum level).

Draft Fans

As indicated above three induced-draft and three forced-draft fans are provided per boiler. They are all direct connected with volume regulation being obtained by means of inlet vanes and louvers. This method of controlling air and gas flow has proved very satisfactory on the 17 large units now operating in four plants.

Control Room

In an effort to reduce the number of operators required, the Authority has adopted the arrangement of one control room for two units. It is located on the turbine room level between the units and between the turbines and boilers. All the principal mechanical and electrical control functions (except switching) are centralized in this room.

By the use of miniature instruments where possible, and by grouping only the trend instruments on the front panels, we have been able to keep the control room size small enough so that it may be staffed by three operators including one who has supervisory responsibilities and may be called away from the control room in emergencies. These three operators in the control room are supplemented in the rest of the plant by three assistant operators and four auxiliary operators per shift for two units.

Piping and Valves

The 1050-F main steam piping is forged and bored and conforms to ASTM Standard A335-P22. This is $2^1/_4$ per cent chromium and one per cent molybdenum alloy. The return steam to the boiler is A106-52T, grade B, seamless carbon steel pipe. The reheat steam to the turbine is A155-52T, $2^1/_4$ per cent chromium, one per cent molybdenum, class 1 rolled and welded alloy pipe. This latter pipe was chosen because it is cheaper than

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[1] Armacost, W. H., "The Controlled Circulation Boiler," ASME Paper No. 53-A-91.

[2] Crossan, T. E., and W. F. Ryan, "Controlled Circulation at Chesterfield," ASME Paper No. 53-A-96.

cupped and drawn or forged and bored.

There are no valves in the main steam piping as the stop valves on the turbine are deemed sufficiently tight. All 1500-pound valves and those for service at 750 F and above have welded bonnets. The 14-in., 1500-pound and the 14-in., 2500-pound valves in the feedwater discharge are venturi-type valves. It was found that the extra pressure drop through these valves was outweighed by their saving in first cost.

STACKS

The two boilers at Gallatin are connected to one concrete brick-lined stack, the top of which is 500 ft above grade. This relatively high stack was chosen to help dissipate the gases from the boiler. The large concentration of generating capacity combined with the rather high sulfur content of the coals available will result in the emission of a considerable volume of sulfur compounds with the stack gases. It has been found that high stacks are one of the most economical ways to dissipate these gases. However, the Authority has a comprehensive program under way, the objective of which is to eliminate or ameliorate the cause of this nuisance, if practicable.

ELECTRICAL CHARACTERISTICS

Each generator is connected solidly to its unit step-up 3-phase transformer which is rated 300 mva, 55 C, FOA, 22.5–161 kv. Three 161-kv lines are connected to a bus section for each generator. Auxiliary power for unit starting and emergency use, and for common station use, is taken from two 25/33.3-mva OA/FA, 161-kv transformers with double 4.16-kv secondaries. Each of these transformers eventually will be connected selectively to two 161-kv bus sections. Auxiliary power for normal use of each unit is taken from a 13.5/18-mva, QA/FA, 22.5–4.16-kv transformer connected solidly to the unit generator-transformer circuit. Controls for the generators and 161-kv switching are on the main control board in the control building located between the powerhouse and the switchyard.

All major auxiliaries which influence plant output, such as draft fans, feed pumps, circulating water pumps, condensate pumps and pulverizers are overpowered. Figures on Gallatin are not yet completed, but on a previous plant it was calculated that each generating unit was able to maintain rated output with frequency reduced to 55.2 cycles at 100 per cent voltage, or with 56.3 cycles at 83 per cent voltage. These figures at Gallatin will be approximately the same.

Conclusion

The authors have attempted to describe some of the more important features of the Gallatin Steam Plant and discuss the reasons for adopting them. Obviously there are many other features which might be included in a paper such as this. Because of the unique characteristics and significance of Gallatin in the power plant field, it is probable that other papers will be written dealing with, among other things, more of the electrical and operating aspects as well as the layout and structural features of this plant.

Petroleum and Natural Gas Reserves

Proved reserves of liquid petroleum and natural gas reached all-time peaks in 1953 despite highest production rates in history, according to a joint announcement by the American Petroleum Institute and the American Gas Association. Proved reserves of liquid petroleum now total 34.3 billion barrels, and those of natural gas 211.4 trillion cubic feet. These represent net increases of 1.4 billion barrels in liquid petroleum and 11.7 trillion cubic feet in natural gas reserves.

Liquid petroleum consists of crude oil and natural gas liquids. The proved reserves of crude oil showed a net increase of 984 million barrels, rising to 28.9 billion barrels as of last December 31. Natural gas liquids reserves went up 441 million barrels, from 4.9 to 5.4 billion barrels.

The additions to proved reserves were accomplished in the face of record breaking withdrawals of oil and gas in 1953. Production of liquid petroleum was estimated at 2.6 billion barrels, and that of natural gas at 9.2 trillion cubic feet.

New supplies of liquid petroleum developed in 1953 aggregated slightly more than four billion barrels. This means that for each barrel of oil withdrawn from the ground last year, the industry found enough not only to compensate for each barrel produced but also to add slightly more than $^1/_2$ barrel to reserves.

With respect to natural gas, new supplies developed during the year amounted to almost 21 trillion cubic feet. In other words, for each cubic foot of gas withdrawn from the ground last year, 1.27 cubic feet were added to reserves.

Steam Purity Determination
II. Methods of Sampling and Testing

By P. B. PLACE

Combustion Engineering, Inc.

This is the second of three articles on the determination of the purity of steam from modern boilers. In the first article, current steam purity test results were subjected to an analysis which suggests that conductivity values obtained by accepted methods represent sampling system contaminations and residual gas effects to a much greater degree than they represent boiler water carryover. This article describes methods of sampling and testing that are useful in tracing sources of suspected or known carryover, determining operating limits of a boiler, and evaluating the purity of the steam, especially when degasification of samples and elaborate test equipment are not available.

METHODS of sampling and testing steam have been established by the ASTM and ASME and any methods suggested here should be considered as supplementary to accepted standards. In some cases, local carryover sufficient to cause superheater failure may not be detected in the standard test procedures, because acceptable readings, say between 0.2 to 1.0 ppm, may be obtained. The term carryover, in this article, refers to contamination in excess of acceptable values.

The principal difference between usual standard methods and these proposed supplementary methods is this. Instead of trying to establish the purity of an average steam sample, the object is to hunt for carryover by sampling in locations where carryover might be expected to register, and to determine the trend in variation in sample conductivity with variations in operating conditions to facilitate interpretation of results. Although such a program may appear to be formidable, a prepared schedule of testing can be completed in two to three days that will give a considerable amount of information of significant value.

In considering a test program, it is highly desirable to anticipate interpretation of results, and to plan to obtain a maximum of information bearing on the questions to be answered. Test results obtained under operating conditions of steady load and low boiler water concentration are obviously of little use in analysis of a carryover problem due to fluctuating load and foaming conditions. Constant conductivity test values of undegassed, or partially degassed, steam obtained for similar load and concentration conditions are not easily evaluated unless test conditions cover a range of rating and boiler water concentration. Thus a testing program should not be a fixed routine, but rather a result of the test engineer's curiosity and imagination, and his ingenuity in devising ways and means to satisfy these characteristics.

Selection of Sampling Locations

A first consideration in such a program of testing will be the selection of sampling locations. In addition to any regular and accepted sampling locations, connections should be installed where carryover would be likely to occur, concentrate, or register. If the steam from the boiler is pure and there is no carryover, then there will be no appreciable difference in test results obtained for an approved sample and a localized, unorthodox sample. If, however, there is carryover, either general or localized, then there is likely to be a difference in results from different locations. This difference is often of more significance than either of the test values individually.

Choice of special sampling locations is subject to the design of the boiler, reasons for testing, and the judgment of the test engineer. If carryover has been indicated by repeated loss of local superheater tubes, it is obviously good judgment to sample that portion of the steam flow in line with the region of failure. Because drum internals are an integrated sequence of separating devices, the failure of any one of which may adversely affect the overall purification performance, it is often desirable to sample within the drum between the different stages of separation. Figs. 1 and 2 show examples of sampling at the saturated header and in the boiler drum.

Sampling at the saturated steam header drain, as shown in Fig. 1, is an example of unorthodox sampling that is useful in some cases. Fig. 3 shows clear evidence of leakage in one end, of the drum internals that registered on a drain sample but was not evident in the conductivity record for the standard header sample. Failure of local superheater elements suggested local carryover in spite of a continuous standard sample conductivity record of less than one micromho degassed. Header drain line samples at the same side of the boiler as the failures showed some 16 mmhos and this conductivity varied with rating, characteristic of leakage carryover. Similar samples at the other side of the boiler registered practically the same conductivity as the standard header sample. The leakage at the south end of the internals was not sufficient to register as carryover in the average sample, but by partial separation and concentration in the header, it was readily identified in the drain line sample. After correction of the leakage, both samples registered practically the same conductivity. Thus, in this case, the difference in test values was significant even though none of the data is quantitative. The cause

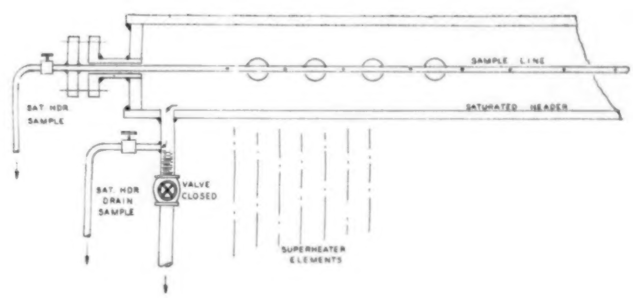

Fig. 1—Saturated header sampling arrangement, above

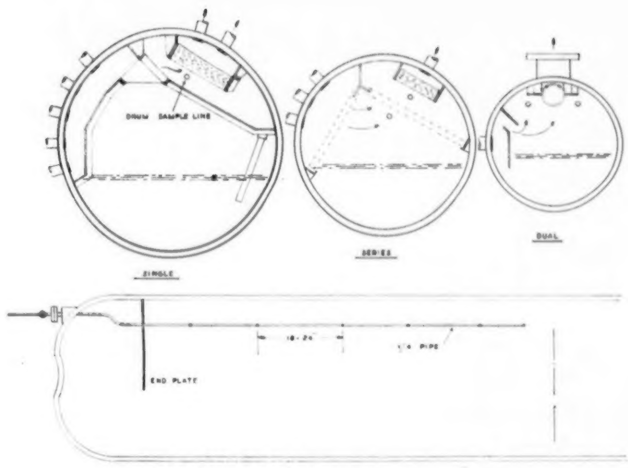

Fig. 2—Examples of drum sampling, drawing on right

of the tube failures and source of the carryover were quickly identified. The leakage was easily located on inspection, and no further trouble has been experienced.

Sampling Lines

After selecting the desired points of sampling, all lines should be run to a convenient, common conductivity testing station. The samples should be individually condensed and arranged to flow continuously through separate conductivity flow cells. By connecting all cells to a common meter through switches, all sample conductivity observations can be obtained at frequent intervals, usually every five minutes if conditions are steady and every two and a half minutes if conditions are varying. Recording instruments can, of course, be used if they are available. Fig. 4 shows an arrangement for a convenient test station.

To insure rapid response, and minimize sampling system contaminations, the sampling lines should be of small diameter and sample flow rates should be liberal. For degassed samples, or permanent installations, an alloy steel should be used, but for temporary lines and drum samples, $^1/_4$- to $^3/_8$-in. pipe of suitable strength can be used. There should be continuous flow in all sample lines from the point of sampling to the condenser without pockets or upflow sections.

It is convenient to hold sample temperatures constant and similar for rapid testing, and this can be done by passing all condensed samples through a common aftercooler ahead of the conductivity flow cells as shown in Fig. 4.

With the equipment set up, sampling lines flushed out, and samples flowing continuously, the test is started by taking observations of operating conditions and sample conductivities. Boiler operating conditions of steam flow, feedwater flow, steam temperature, steam pressure, and water level are pertinent data to be recorded, with notes on such other conditions as popping safety valves, blowing flues, blowing down, or feeding chemicals to the boiler. Boiler water samples and feedwater samples should be checked every half hour or every hour, dependent on the degree of variation.

Setting Accuracy Standards

It is very desirable to establish a regular schedule of observations and to set up accuracy standards for the data. A good rule is to limit the accuracy of observations to the limit of accuracy desired in the plotted results. A little experience will establish these limits for the individual test involved. For example, water levels seldom need to be read closer than the nearest inch or recorder values closer than the nearest scale division on the chart. Conductivity of a degassed steam may be measured as accurately as time and interest permit, but conductivity of drum steam samples, feedwater and boiler water require no great accuracy and can be read to the nearest mmho or nearest ten mmhos, dependent on the total value. The reason for setting accuracy limits is that, during periods of rapid fluctuations in steam flow or conductivity values, readings may have to be taken "on the run" and it is more important to record the data on schedule than to lose time trying to read them with extreme accuracy.

Operating conditions are then varied over the expected range of normal and abnormal operation without break in the sequence of test observations. Steam rates, water levels and boiler water concentrations are the principal factors to be checked. In order to properly evaluate the effect of variation in any one factor, all other operating conditions should be held reasonably constant during such variation. Steam rates should be varied from a banked period to full load. Water levels should be varied over the controllable range and boiler water concentrations from as low as possible to well above normal, and up to the foaming stage if possible.

Any given set of operating conditions should be held until variations in conductivity of the samples stabilize. This should not require more than 15 or 20 minutes. Thus, a great many variations in operating conditions may be covered in a day or so of testing. It is seldom necessary to cover all of the tests suggested above as results for some conditions can be assumed from the results of other tests. For example, if a boiler is not sensitive to changes in rating and water level with high boiler water concentration, it can safely be assumed that it will not be sensitive to similar changes in rating and water level with low boiler water concentration.

Planning the Test Program

With a little planning, the test program can be arranged to give a maximum of information with a minimum of testing and variation in operating conditions. It is usually desirable to establish steam purity conditions for a low and non-foaming boiler water concentration.

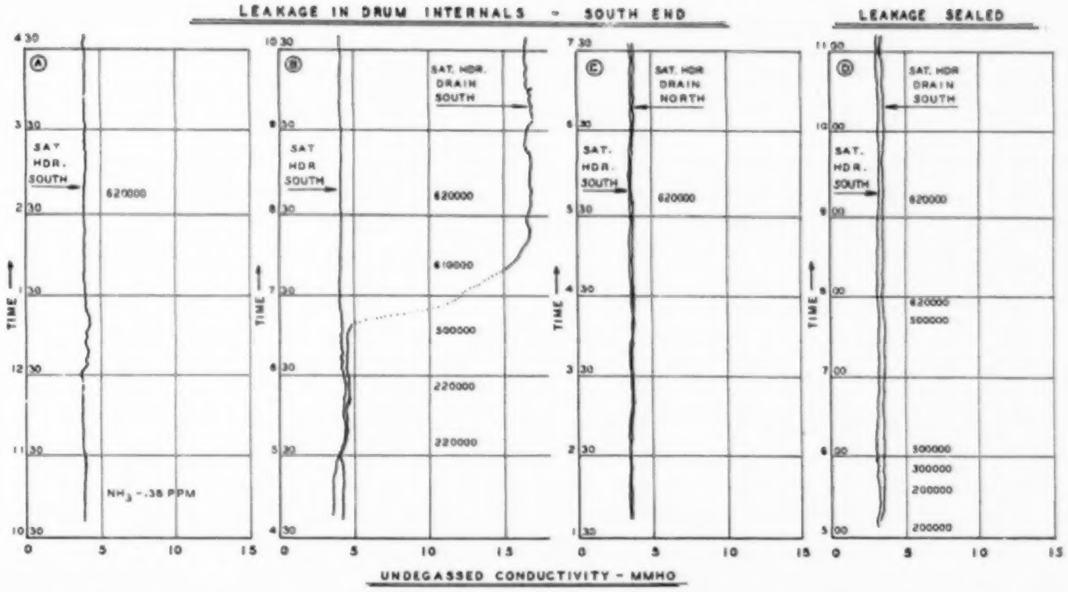

Fig. 3—Failure of local superheater elements in one installation suggested local carryover, yet sample at saturated header, A, above, indicated high purity steam. But a sample taken from drain connections at south end of header, B, indicated leakage in drum internals. A sample drawn from the drain connections at north end of header, C, showed a good quality steam in that section, thereby isolating the leakage area. After corrections of leakage both header and header drain samples, D, indicated a high purity steam and there were no further superheater failures.

Any limitations that may develop under such conditions will be of a mechanical nature that obviously will not be improved by increase in concentration. Limitations of chemical origin can then be investigated by repeating the tests at higher boiler water concentrations.

Tests at high boiler water concentrations that may result in foaming and sudden heavy carryover to the superheater can be kept under control by watching and interpreting the reaction of a drum sample to the variations in test conditions. A sample taken at the dryer inlet, as shown in Fig. 2, will reflect the development of potential carryover and steps can be taken to control the condition before the dryer becomes overloaded and actual carryover occurs. The ratio of the conductivity of the drum sample over the conductivity of the boiler water is a measure of the wetness of the steam. In the absence of foaming, this ratio will represent the normal spray conditions in the drum and both the conductivity of the sample and the ratio will vary with changes in rating and concentration. These variations will be fairly consistent with the premise that the amount of spray should increase with rating, and the conductivity of the spray should increase with higher boiler water concentration.

Sudden and excessive rise in the conductivity of the drum sample and the ratio gives evidence of a change in the physical characteristics of the moisture in the steam, which is indicative of foaming. Recognition of this potential carryover usually allows time to reduce rating and concentration before it endangers the superheater. Examples of drum sample test results will be discussed in the third article of this series.

In many cases degasification of boiler outlet steam samples is inconvenient and conductivity test values ranging from less than one mmho to over 4–5 mmhos may be obtained. If such values show some consistent variation with changes in rating and boiler water concentration it is likely that minor carryover is occurring, probably due to leakage in the drum internals. If the values, however, are fairly constant regardless of rating and concentration variations it is likely that steam purity is satisfactory and that most of the conductivity value is due to sample contamination and residual gases in the sample.

Evaluation of Test Results

In order to evaluate satisfactorily such test results, it is desirable to include a test at the lowest possible boiler water concentration with the boiler on bank or operating at very low output. Such a test, under conditions that should logically give a minimum of carryover and lowest possible conductivity results, is similar to the determination of a "normal" in steam calorimetry. If the conductivity test values under such operating conditions are not lower than at the high ratings and high concentrations,

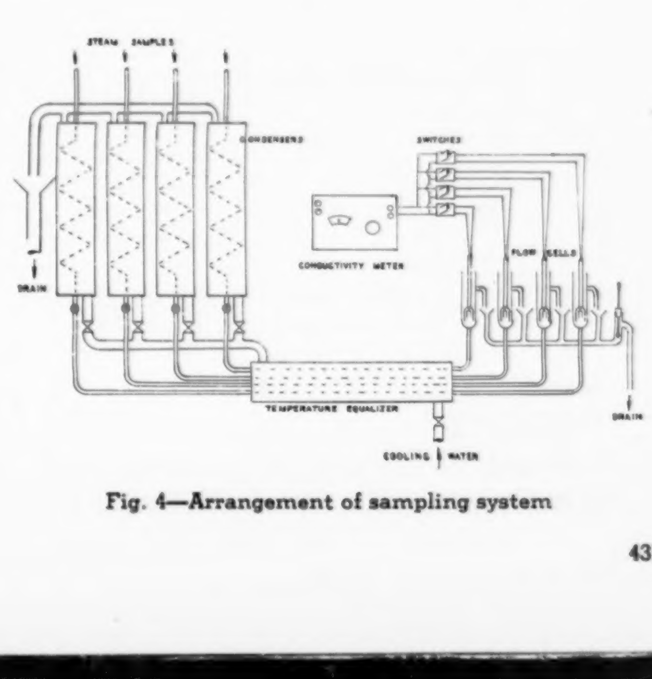

Fig. 4—Arrangement of sampling system

they provide assurance that a major portion of the conductivity must be due to other than boiler water carryover.

In many cases, conductivity values at low ratings and low concentrations will be greater than at high ratings and high concentrations due to the difference in gas evolution under the two operating conditions. For example, a low concentration obtained by increase in blowdown involves a proportionate increase in feedwater flow and corresponding increase in gases in the steam. Further, the lower concentration may involve a reduction in pH conditions of the boiler water and a change in chemical equilibrium that results in higher gas content in the steam. Variations in steam sample conductivity, due to variations in gas content, can also be produced by changes in makeup water supply or by chemical dosage. Notes on such conditions should be kept during the test period so that results may be properly evaluated.

When the test schedule is completed, the collected data are plotted against time. Any variations in conductivity can then be directly correlated to some change in operating condition and a logical interpretation of the data made. If the test program is extensive it may be advantageous to plot the data as they are collected so that the trend in results can be followed, and the program of test varied or expanded to obtain confirming or additional information.

In plotting the results, the scale divisions on the chart should be chosen to conform with the significance of the data. For example, a 0.1-inch change in water level in a boiler is of no significance and there is no point in plotting such levels to a scale of ten divisions to the inch. It is seldom necessary to collect or plot data for time intervals of less than two and a half minutes. Graph paper having more than ten divisions to the inch should not be used and plotting all of the data of a test on one large chart is to be preferred to plotting it on a series of small charts. It is also desirable to include a sketch on the chart showing the location of sampling points as well as any notations pertinent to the interpretation of the data.

In a subsequent and final article of this series, examples of test results will be discussed in some detail to illustrate methods of interpretation. These examples will be selected to show some feature of interpretation and to suggest new viewpoints on the evaluation of steam purity test results.

Flyash for Road Construction

Bituminous Coal Research, Inc., keeps abreast of technical developments which affect the production, use and marketing of coal.

One such development they have followed closely and on which they reported in their June–August 1953 publication, *Bituminous Coal Research*, is utilization of flyash from electric utility plants. If this flyash is aggressively marketed they feel the utilities can write it off as a disposal problem. What's more by selling the flyash they reduce the net cost of the coal they use. And there are definite markets for this flyash. For instance flyash has been found to have value in the construction of bituminous and concrete roads, concrete block and drain tile, and similar products.

Important pioneering work in these fields has been accomplished by such groups as Detroit Edison Co., Commonwealth Edison Co. of Chicago through the Chicago Fly Ash Co., G. & W. H. Corson Co. with several eastern utilities, and Walter N. Handy Co. These groups have made their experience available.

In response to a request for a bituminous road in the Appalachian area BCR enlisted the support of Duquesne Light Co. of Pittsburgh who offered to build a demonstration roadway at its Phillips Power Station, near Ambridge, Penna. This strip of roadway, 180 ft. long, 80 ft. wide at its entrance, and 30 ft. wide at the stockpile end, connects the state highway to the power station's coal stockpile.

Each day 300 to 400 trucks loaded with 10 to 15 tons of coal travel the length of the strip. Various combinations of standard- and flyash-containing surfaces and bases were installed to demonstrate the work of flyash in such roadways. All sections were laid crosswise so every truck must pass over every section. The construction differed from standard heavy traffic roadways only in that flyash was used as a replacement for limestone dust in the surface and as a replacement for 1-A slag for "choking" the base courses.

State and city highway department officials inspected the comparative roadway and could find no difference in the surface containing flyash and the standard surface, as of the time of the inspection, just ten days after the strip was laid down. Other inspections are scheduled for later dates.

The importance of this discovery for application of flyash is shown by the fact that 580 tons of flyash would be used to choke an 8-in. base course for each 11 ft. wide, mile-long lane of highway; 34 tons would be used in the one-inch surface course, and 12 tons in the two-inch binder course.

Flyash has frequently been used as an ingredient in bituminous surfaces and concrete elsewhere in the country. Up to the time of this report, though, BCR had not been aware of any other instance where the flyash was employed for "choking" the voids between the lumps of slag or crushed stone in the road base. The Allegheny Asphalt and Paving Co. who laid down the roadway found the flyash in the choking operation ran into the voids without the hand work that is necessary to brush the conventional fine slag down into these same voids. Further they reported the surface of the sheet asphalt containing flyash handled easier.

*Economy of Large Generating Units**

By H. P. SEELYE†
and
W. W. BROWN††, Detroit, Edison Co.

Optimum pressures and temperatures, relative capital outlays and operating costs, plus any possible fuel savings are among the factors to reckon in selecting power equipment. Here's how one large utility evaluates proper unit size.

LAST November, The Detroit Edison Company began construction of a new power plant at River Rouge, Michigan, near Detroit, which will have generating units of a maximum rated capability of 260,000 kw each. The first two units of this plant, the sixth largest thermal plant on the Company's system, are scheduled to go into operation in April and November of 1956, respectively. They are the largest units which have as yet been placed on order with the manufacturers. This record for size was only incidental, however, and played no part in the choice since other units as large as 250,000 kw are already under construction. The decision was, rather, based on a careful study of the economy of various sizes from 150,000 kw up, and the evident cost advantage to be gained from the large capacity. The chief points covered in this study and the economic relationships which were disclosed appear below.

The units chosen are to be cross-compound double-flow, with approximately 60 per cent of the capability in the high-pressure machine at 3600 rpm, and 40 per cent in the low-pressure machine at 1800 rpm. Steam conditions will be 2000 psig, 1050 F, with 1000 F reheat, with a single boiler per unit. One turbine generator will be manufactured by the General Electric Company, one by Westinghouse Electric Corporation; one boiler will be from Combustion Engineering, Inc., and one from Babcock and Wilcox Company; condensers will be made by the Allis-Chalmers Manufacturing Company.

The cost studies on the plant covered (*a*) type of generating units, (*b*) size of generating units and (*c*) plant steam conditions, assuming a two-unit plant initially.

Selection of Generating Unit Type

Cost comparison studies of turbine types included installed costs of turbine generator, steam generator, building and plant auxiliaries. Three types were considered, (*a*) cross-compound double-flow, (*b*) similar type of cross-compound but single-flow and (*c*) tandem-compound triple-flow. Table I shows the cost relationships between the three types, in terms of the increment above the cost for the type having the lowest cost for each item.

As shown in Table I and Fig. 1, the comparison shows that, on the basis of an average 56 per cent plant factor for a 35-year life, the appreciably better heat rate and resulting fuel savings of the cross-compound double-flow unit offsets its higher investment cost. The present worth of the large coal savings in the early life of the plant as compared with the somewhat smaller savings in the later years was taken into account in the calculation. Another important factor is the relatively low temperature of cooling water prevailing at this location. This justifies the calculation using heat rate at 1 in. Hg back pressure and actually produces less than 1 in. at times. This condition is favorable to the cross-compound unit as compared with the tandem-compound.

Two combinations of load division between the high- and low-pressure turbines were studied. The first placed 40 per cent on the high-pressure turbine and 60 per cent on the low-pressure turbine. The second combination placed 60 per cent on the high-pressure turbine and 40 per cent on the low. The latter arrangement proved to be more economical.

Selection of Size

Studies were made for generating units of 156, 175, 200 and 260-mw maximum capabilities. It early became apparent that 200-mw units would effect savings of the order of 10 per cent in overall plant cost as compared with 175-mw units, and similar possibilities were found in the comparison with still smaller units. It was suggested by the turbine manufacturers that a cross-compound unit with a 260-mw rating might have a cost per kw comparable with that of a tandem compound, 200-mw unit. This suggested a study of the larger unit. The favorable comparison was borne out when evaluated coal savings for the cross-compound unit were included in the calculation.

Table II shows the cost relationships between total plant costs for 260- and 200-mw units for a two-unit plant, in terms of the increment for the 260-mw size above the 200-mw size.

The relatively low incremental cost for the 120-mw obtained by using the larger units is due partly to the somewhat lower cost per kw of the equipment itself, and also the several major items whose cost is little affected by the difference in the size of the unit. These items are site, site development, building, coal handling, instrumentation, design and engineering and certain field construction costs. There is a small advantage in heat rate for the larger unit but this is insignificant as compared with other items and is not included in the table.

Selection of Steam Pressure and Temperature

The several different plant steam conditions studied were (*a*) 1800 psig—1050 F—1000 F; (*b*) 1800 psig—1050 F—1050 F; (*c*) 2000 psig—1050 F—1000 F; (*d*) 2000 psig—1050 F—1050 F. Each of these condi-

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TABLE I—INVESTMENT DIFFERENCE BETWEEN TURBINE TYPES OF 260 MW CAPABILITY

	Cross-Compound Double-Flow (CCDF)	Cross-Compound Single-Flow (CCSF)	Tandem-Compound Triple-Flow (TCTF)
Turbine generator	+$420,000	+$17,000	0
Steam generator	0	+215,000	+$215,000
Auxiliaries (heaters & pumps)	0	+57,000	+37,000
Building	+260,000	+97,000	0
Total plant compared to TCTF	+408,000	+114,000	0
Heat rate difference (capitalized at $12^1/_2$%; 35¢ per 10^6 Btu coal; 56% annual plant factor; 1 in. Hg B.P. interest accretions credit)	0	+509,000	+623,000
Investment adjusted for heat rate	+408,000	+623,000	+623,000
Net investment adjusted for heat rate compared to CCDF	0	+215,000	+215,000

TABLE II—POWER PLANT COST COMPARISON

2-200 Mw Compared with 2-260 Mw Units both Cross Compound

	Two 200 Mw	Two 260 Mw
Main power station building	0	+$ 400,000
Boiler plant equipment	0	+3,300,000
Turbine generator plant	0	+2,165,000
Accessory electrical equipment	0	+100,000
Station equipment—transmission	0	+335,000
General items, contingencies, escalation, interest		+1,100,000
Total		$7,400,000
Incremental cost per kw for 120 Mw		$61.67
Total plant cost per kw	$172.50	$146.92

Comparison tables point up investment differences between turbine types based on a 56 per cent plant factor, left and cost differences between specific sizes, above.

tions was compared to 1800 psig—1000 F—1000 F reheat which is used in the most recent plant (St. Clair Power Plant) now in operation on the Detroit Edison system. As may be seen from Table III, only the 2000 psig—1050 F—1000 F reheat and the 2000 psig—1050 F—1050 F reheat conditions provided sufficient return on the increased investment to justify further consideration.

The fuel savings for the higher temperatures and pressures do not provide a high return on the required additional investment in any case and particularly for the two at 1800 psig, for which the return is less than the $12^1/_2$ per cent assumed elsewhere in this study. Although the net return for the 2000 psig was also rather small, it was decided to choose an advance in steam conditions in view of increasing fuel costs and the desire to take a progressive step in power plant design. Consequently 2000 psig—1050 F—1000 F reheat was selected. A reheat temperature of 1000 F instead of 1050 F was chosen because it was felt that the higher temperature would involve metallurgical problems which might result in increased maintenance costs tending to offset the small net return.

Investment Comparison

A cost comparison of generating units must, of course, take into account not only the cost of the plant but also the cost of transmission facilities to deliver the power to points of distribution on the system. Summarized cost estimates for the two sizes of units being studied, as applied to the specific location on the Detroit Edison system appear in Table IV:

Figures for 2 and 3 units of each size are shown because it is likely that the early installations in the plant will be no more than three, and also they give a comparison between somewhat similar amounts of total capability for three 200 mw and two 260 mw. Figures for a large number of units can be derived by the assumption that increment costs for additional units will be the same as for the third unit, although such assumption is relatively unreliable, due to the uncertainty of the trend of future costs.

The following points are significant:

1. Although the investment required for the first two units is $9,500,000 greater for the 260-mw size than for the 200-mw, 30 per cent more capability is obtained, with an average cost $25.17 per kw less. The additional 120 mw is obtained for an additional investment of only $79.17 per kw for plant and transmission.

2. Three 200-mw units give a total of 600 mw, or 80 mw more than 2—260-mw units, but the investment is $17,700,000 more, or $221.25 per kw for this addition.

3. Three 260-mw units total 180 mw more than three 200-mw units, a cost of only $14,100,000 more or $78.33 per kw for the additional amount. The 780 mw with the three larger units have an average cost of $21.14 per kw less than the 600 mw with the 200-mw size.

4. If a completed plant with six units is assumed, with a uniform increment cost per unit, for the third to the sixth units, the average cost per kw would still be about $15 less with the 260-mw units than with the 200-mw. The 260-mw units have also the very real but somewhat intangible advantage of making more effective use of the site, that is assuming a limit of six units, there could be 30 per cent more capacity on the site (360 mw) with the larger size. This is important where suitable sites are scarce.

Annual Cost Comparison

The comparison between the two sizes of unit can best be summarized by a consideration of annual costs, assuming the two-unit plant.

(*a*) For a difference in investment costs of $25 per kw, the annual carrying charges at an assumed rate of $12^1/_2$ per cent would be $3.13 per kw per year.

(*b*) Operating and maintenance costs for the larger unit should be less, since it would not take proportionately more labor for the larger machine. The difference for the case under study was estimated at $0.42 per kw per year, which is 13 per cent of the estimated cost for the smaller unit.

(*c*) The difference in fuel cost has been indicated to be relatively insignificant being of the order of $0.02 per kw per year, in favor of the larger unit.

(*d*) The sum of these savings is $3.57 per kw per year.

This amounts to $357,000 per year for each 100,000 kw of plant capability.

For additional units above two, the advantage of the larger unit becomes somewhat less but with the six-unit plant the average is still of the order of $230,000 per year for each 100,000 kw.

Pertinent Questions

A number of questions in regard to possible disadvantages for the larger unit were given consideration. These were all essentially economic, that is, related to offsetting costs which might be incurred, although they could not be very definitely evaluated.

(*a*) Would the reliability of the generator on the 3600-rpm shaft be any less with the larger unit (156 mw

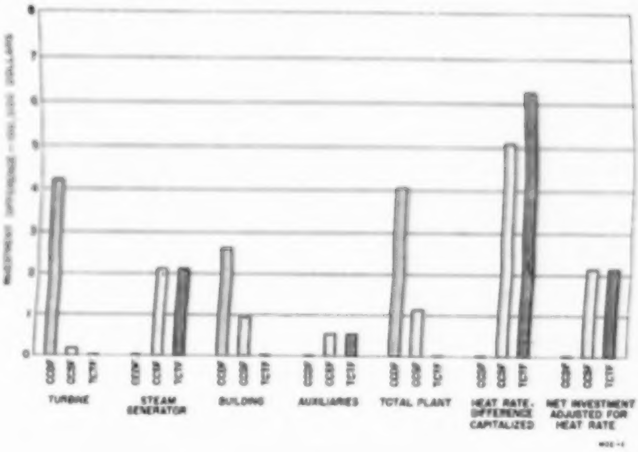

TABLE III—COST COMPARISON OF STEAM CONDITIONS IN TERMS OF INCREMENT COSTS ABOVE THE COSTS FOR 1800 PSIG—1000 F—1000 F REHEAT

	1800 Psig 1050 F 1000 F Reheat	1800 Psig 1050 F 1050 F Reheat	2000 Psig 1050 F 1000 F Reheat	2000 Psig 1050 F 1050 F Reheat
Steam generator	\$126,000	\$280,000	\$216,000	\$370,000
Turbine generator	134,000	251,500	170,000	295,100
Piping	20,000	30,000	30,000	40,000
Feedwater heaters	0	−3,800	40,000	40,000
Pumps and drives	0	0	15,000	15,000
Condensers	−5,000	−10,000	−10,000	−16,000
Total	\$275,000	\$547,700	\$461,000	\$744,100
Annual Saving Resulting from Reduced Heat Rate				
Annual coal savings 35¢ per 10^6 Btu coal	\$30,930	\$61,860	\$64,840	\$100,040
Pump power saving	440	880	−5,360	−5,000
Net annual saving	\$31,370	\$62,740	\$59,480	\$95,040
Per cent return on additional investment	11.4	11.4	12.9	12.8

Data making up Table I are arranged in bar chart, left

on one of the machines) than with a smaller one? If such should be the case, it would lead to additional outage time with the attendant high cost for repairs and for loss of generating economy.

There has not been a wealth of experience with 3600-rpm machines of such a size. Some have been built and put into operation, however, and still larger ones, up to 250 mw are under construction. The temperature rises offered for the designs were conservative, and other features appeared to be reasonably well established by experience. It was concluded that there was no good reason to expect any less reliability with the size proposed than with a smaller size.

(*b*) Would a 260-mw unit be out of proportion to the size of the system? If it were, the removal of the unit from service, due to its failure or for necessary maintenance, would be relatively more serious than with a smaller unit. The net effect might be to require more system reserve.

Examination of the proportional size of previous units on this system over the past 30 years indicates that, when a new larger size has been introduced, it has been between 10 and 15 per cent of the system load with the exception of the most recent addition which was $7^1/_2$ per cent. The proposed 260 mw is about 10 per cent of the expected load in the year in which it will be installed. Furthermore, the system is different now than previously, in that it is well interconnected with other systems into a total of about 8 million kw. A 260-mw unit is not large in comparison.

It might be inferred that a larger unit would require somewhat more system reserve to provide against its outage than would a smaller one. Reserve is considered in terms of a percentage of system load, however, so if this indicates an amount as great as the size of the unit, no additional amount should be necessary, particularly in a power pool of the size which has been mentioned. No additional cost is therefore anticipated for the larger unit on this account.

Some minor expenditures might possibly be incurred during the first few years after the installation of the large unit for maintaining a desired amount of running reserve on the system during outage of the unit. This is problematical and estimated to be relatively insignificant in any case.

(*c*) Would the larger size of unit have any serious adverse effect on the transmission system? This refers to possible excess transmission costs, heavy concentration of loading at transmission terminal stations and increase in short-circuit duty requiring larger circuit breakers or means for moderating this effect.

Most of the transmission out of this plant will be by 120-kv underground cable. At least two lines from each generator section will be used, terminating in different stations. The generator sections will be tied together at the plant through reactors to a star bus. With this design, no disproportionate effects on transmission costs are foreseen.

(*d*) What additional carrying charges will be incurred with the larger size due to the greater length of time required for system load growth to load the unit?

It is practically impossible to get a realistic answer to this question. Load growth varies, and the load varies throughout any year. The timing of new units does not depend directly upon the load growth but involves other factors of maintenance time, provision for unforeseen growth, possible margins for rebuilding old plants, power available for purchase from interconnections, or possible sale to interconnections, and many others. A theoretical study on the assumption of steady uniform growth with machines coming on just as needed indicated a possible offsetting charge of something like \$150,000 per year per unit. This should not be considered too seriously, however, since there might be as much real advantage in having more power available to meet unexpected load additions. At least this factor does not appear large enough to seriously affect the economic advantage shown for the larger unit.

Design Data

Although the purpose of this paper is to discuss the economic advantages of a large unit, it may be of interest to indicate some of the quantities wherein the size of the unit is reflected in the design data. For example, condensing circulating water flow per unit is 150,000 gpm, while the condenser cooling surface is 115,000 sq ft. Motor sizes for auxiliaries are 4000 hp for each boiler feed pump and 2500 hp for each induced draft fan. Primary turbine throttle flow at maximum rated capability is 1,650,000 lb steam per hour, supplied through two $17^1/_2$-in. O.D. × $3^1/_4$-in. wall thickness pipes connected to the boiler through a 21-in. O.D. × $3^3/_4$-in. wall thickness pipe. Pipes will be $2^1/_4$ CR, 1 Mo steel pressed and drawn.

The main unit transformer will be the largest ever built and will be three phase, rated at 315,000 kva; pri-

TABLE IV—SUMMAR D COST ESTIMATES

	Plant Cost		Transmission		Plant & Transmission Total	
Two—200 mw (400)	$69,000,000	$172.50	$6,300,000	$15.75	$75,300,000	$188.25
Three—200 mw (600)	94,300,000	157.17	8,200,000	13.67	102,500,000	170.83
Two—260 mw (520)	76,400,000	146.92	8,400,000	16.15	84,800,000	163.08
Three—260 mw (780)	104,600,000	134.36	12,000,000	15.41	116,600,000	149.69

mary voltage 17,300, secondary 129,000; taps will be provided for 126, 123, 120 and 117 kv. The cooling system will be forced oil, air cooled.

In considering the development of the site for the ultimate plant of six units (1,560,000), the following design data for consuming, reclaiming and storing coal were important.

Maximum daily consumption	14,500 tons
Annual consumption.......	4,250,000 tons
Maximum rate of supply to plant bunkers............	2200 tons per hour
Maximum unloading rate from ships..............	2200 tons per hour

Since much of the coal delivered to this plant will be water borne, it is necessary to provide for 1,800,000 tons coal storage on the site, sufficient to last during the Great Lakes off-navigation season, plus a margin on hand when navigation resumes.

Conclusion

The analysis of costs and other intangible factors which have been reviewed here is believed to have warranted the conclusion that there are appreciable advantages and no serious disadvantages in adopting a size of generating unit which is relatively as large in comparison with the system load as the one which has been ordered from the Detroit Edison system. Still larger units are being proposed by the manufacturers and it is not at all unlikely that some of these will prove equally advantageous when later additions are to be made.

Water-Resistant Insulation Passes Rigid Tests

Development of a new water-resistant insulation has been announced by The Magnesia Insulation Manufacturers Association representing the producers of 85% Magnesia insulation and related products. The new form of 85% Magnesia for hot piping and equipment offers a solution to the important problem of insulation damage resulting from severe water exposures. Exhaustive tests by the Pittsburgh Testing Laboratory indicate that immersion in boiling water for 378 hours with intermittent drying on hot pipes caused only a slight roughening of the insulation surface with no loss of insulating values. Following the tests, the new product was still in serviceable condition.

The new insulation was developed under the sponsorship of the Technical Committee of MIMA and is the result of several years of research and development in the laboratories and plants of the member companies. It is said to be especially useful for underground pipe lines subject to flooding, process equipment and piping requiring hosing or washing down, and similar conditions.

For all practical purposes, the water repellent additive in the new material does not affect the conductivity, density or other vital properties of the insulation. Conventional 85% Magnesia insulation, will continue to be the industry's standard product, and the new water resistant material will be offered only where severe moisture problems exist or when specified by the user.

In tests conducted by the laboratory, water resistant 85% Magnesia on hot steam pipes was subjected to 30 cycles of immersion in boiling water, each cycle consisting of seven hours immersion and 17 hours drying, plus an additional 168 consecutive hours of immersion. After each immersion, the steam pipes carrying 125 to 140 psig steam dried the insulation thoroughly. Examinations were made between cycles and at the conclusion of the tests for disintegration, cracking, spalling, shrinking or other damage.

At the end of the tests, the new water resistant insulation, according to the laboratory report, was found to be intact with surfaces rougher but with joints firm and in good condition, no appreciable shrinkage, and no swelling or cutting in of bands. The report stated that it "was found to be highly resistant to disintegration under test conditions of continuous steam flow while immersed in boiling water".

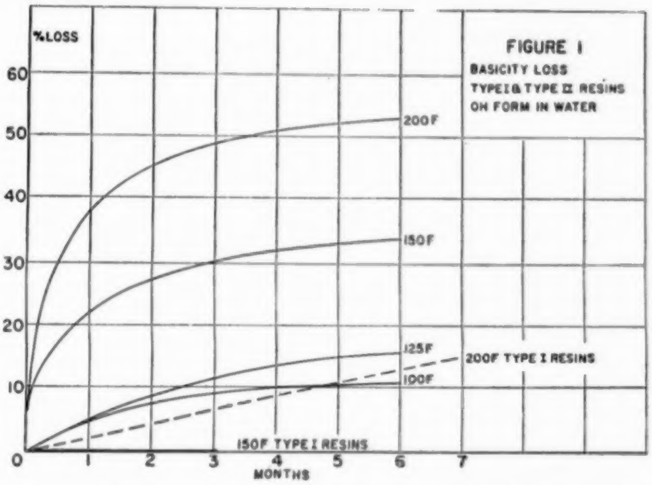

Fig. 1—Temperature effect on basicity loss of type I and type II resins shows a pronounced degradation increase with an increase in temperature

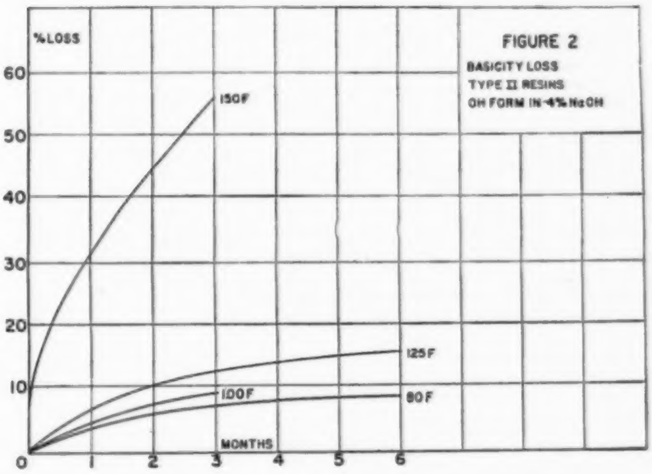

Fig. 2—Degradation of type II resins accelerates sharply with caustic soda solution at temperatures around 150 F so regeneration should occur at 95 to 100 F

The Expected Life of Anion Exchangers*

Attempts have been made and guarantees offered in the past on the useful operating life of highly basic anion exchange resins without suitable substantiating evidence. Here is the first compilation of operating data aimed at estimating resin life and some of the influences the data reveals.

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AVAILABLE information on the stability characteristics of the highly basic anion exchangers up to now has been limited to laboratory studies and scattered reports of operating experiences. Of necessity efforts to arrive at suitable amortization rates for these products have involved considerable extrapolation and at times some pure guesswork. Guarantees of resin life have been made by equipment manufacturers without the benefit of long term operating data. But at last sufficient operating data have been accumulated to allow a coordinated approach toward estimating the useful life of the highly basic anion exchangers. Several factors of significant influence on resin life seem clear, as follows:

1. The selection of the proper type of anion exchange resin for the conditions of water supply being deionized determines to a great extent the useful life of the resin and its operating costs.
2. Anion exchange resin life increases considerably with reduction of the oxygen content of the water passing through the anion exchanger. When considering large deionizing installations, it pays to investigate thoroughly the value of vacuum deaeration for nearly complete gas removal as contrasted to the common decarbonator. There are many other advantages to be gained through the use of the vacuum deaerator.
3. Organic matter in the water supply imposes a problem of capacity shortage and poor water quality which, however, should not be confused with that caused by the normal degradation rate of the highly basic anion exchange resins.
4. The economically useful life of the contemporary strong base anion exchangers may be as little as 5–6 years. In certain instances shorter periods of life may be expected and in others longer life will be realized.
5. Several deionizers under study were not sufficiently conservative in design to assure adequate operating exchange capacity. Accordingly more conservatism of design is to be encouraged. This can be helped a good deal by more careful preparation of specifications.

Anion Exchange Resin Development

Between 1945 and 1950 demineralizing water methods greatly improved with the new silica removal processes made possible by the development of a series of anion exchange resins exhibiting silica removal properties. As late as 1947 the only products of this type available were of the amine type (1) which contained only a relatively small proportion of quaternary amine groups. The balance of the exchange groups was weakly basic in nature and possessed no silica removal capacity. Two

* Presented before the Sixteenth Annual Meeting of the American Power Conference, sponsored by the Illinois Institute of Technology, Chicago, March 24–26, 1954.

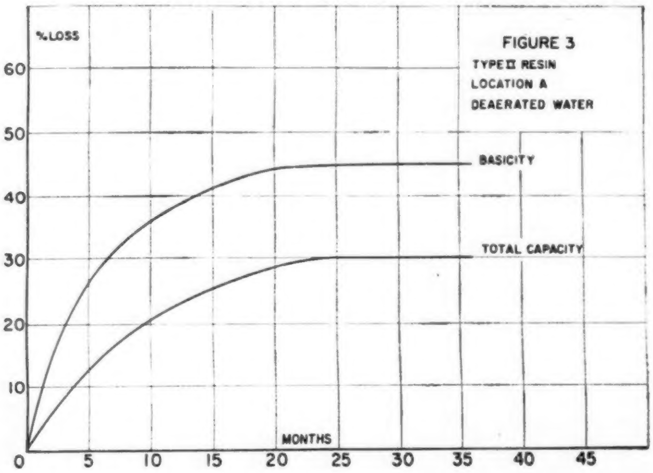

Fig. 3—Samples taken every six months permit a picture of basicity loss of a resin working with a deaerated water supply as in the above

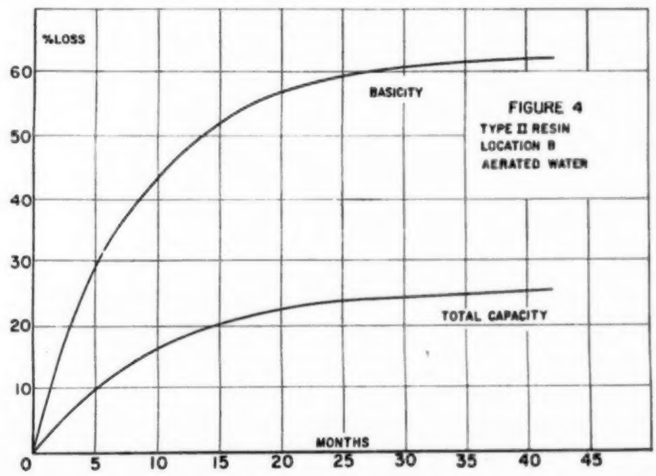

Fig. 4—Comparison between aerated water under tests, above as against a deaerated supply, Fig. 3, indicates a greater loss of basicity over the period of time studied

types of highly basic quaternary amine anion exchange resins, both of styrene base composition, were developed shortly afterward. The first of these materials (2) was applied primarily for removal of silica from water and the second (3, 4, 5) for the removal of all anions including silica, since it had more favorable exchange capacity at fairly efficient regenerant levels.

The use of any of these products was quite limited prior to 1950. But in the past three years we have learned considerable of the operating characteristics of the highly basic anion exchangers such as their limitations and something about their useful operating life.

New Products Stability

In 1951 a paper presented by M. E. Gilwood at the 12th Annual Water Conference at Pittsburgh (6) described a condition of degradation of highly basic anion exchange resins as evidenced by laboratory evaluation of these products. F. K. Lindsay at the time, however, disclosed information that indicated capacity losses evidenced in laboratory studies were not too strongly felt with actual operation of the resin in a deionizing unit. These findings have now been expanded to include data representing nearly four years of operating experience. Out of these data there is much that will add to the knowledge of anion exchanger stability characteristics and also improve the understanding of their applicability to the deionizing operation both from operational and economic points of view.

In the Gilwood paper (6) the highly basic anion exchange resins were identified as type I and type II. For purpose of uniformity this method of identification is maintained throughout the contents of this paper.

Investigation of the Problem

Laboratory study, we know, offers useful information which often serves as a guide to the application of products. In Fig. 1, for example, a study of water temperature effect on basicity loss of type I and type II resins shows clearly a pronounced rate of degradation increase with an increase in the environment temperature. We carried out the same study, Fig. 2, with type II resins in the environment of a regenerant solution of 4 per cent sodium hydroxide. It is important to note that stability in water and also in a 4 per cent sodium hydroxide solution at temperatures below 125 F proved practically identical under these test conditions. This point will be discussed in more detail later.

In addition to laboratory studies we felt we needed data that would characterize the operating life of the anion exchange resins so periodic evaluation of materials in actual operating use became necessary. The value of such data becomes greater if it includes widely varied water supplies being deionized under practically identical conditions such as regeneration and operating flow rate. Accordingly two installations of type II resins, which we know are among the oldest on record, have been used as the basis of this study because of the availability of samples at frequent intervals. Spot sampling at several other locations of known operating circumstances have made it possible to fit all of the data obtained into a pattern which depicts resin life. At least 15,000 cu ft of highly basic anion resin were in use at the several locations included in this study with about 25 per cent being the type I resin. The large bulk of the deionized water was and is used for 1250-psig steam generating purposes.

The purpose of this study is to characterize the changes in resin structure that result in a loss of silica removal capacity, and also a loss of ultimate capacity. Silica removal capacity is commonly termed as basicity, and the ultimate capacity is commonly termed as total capacity. In Fig. 3 the progress of basicity and total capacity loss experienced with type II resin at location A is plotted against time. This resin has operated on a water supply which has been deaerated previous to passing through the anion exchanger. Thirty-two hundred cubic feet (3200 cu ft) of anion exchanger are contained in 5 units.. Regeneration frequency averaged once a week, regenerating at 95 F and the several units involved operated at a flow rate of 5–7 gpm/sq ft. A 60-in. bed of type II resin was used.

Fig. 4 records similar data from location B which has operated with the water passing through the anion exchanger practically saturated with oxygen. Regeneration frequency approximated 10 per week, regenerating at 95 F with an operating flow rate of 5–7 gpm/sq ft. A 60-in. bed of type II resin is used.

TABLE I—TYPE II RESINS STUDIED

Location	Water Supply	Regeneration/Week 1–2	about 10
A	Deaerator-Surface Water	A	
B	........Surface Water		B
C	Aerator Surface Water	C	
D	Aerator Surface Water		D
E	Aerator Surface Water	E	
F	Aerator Well Water	F	
G	........Surface Water		
H	Aerator Surface Water	H(5/wk.)	
I	Aerator Surface Water	I	
J	........Surface Water	J	

TABLE III—ANION EXCHANGE RESIN APPLICATION

Anion Exchange Resin Applied	For Removal of
Weakly Basic	Sulfate, chloride and nitrate*
Type I highly basic	70–75% weak acids or greater†
Type II highly basic	25–30% weak acids or less†

* Strong mineral acids.
† Weak acids are CO_2 and silica.

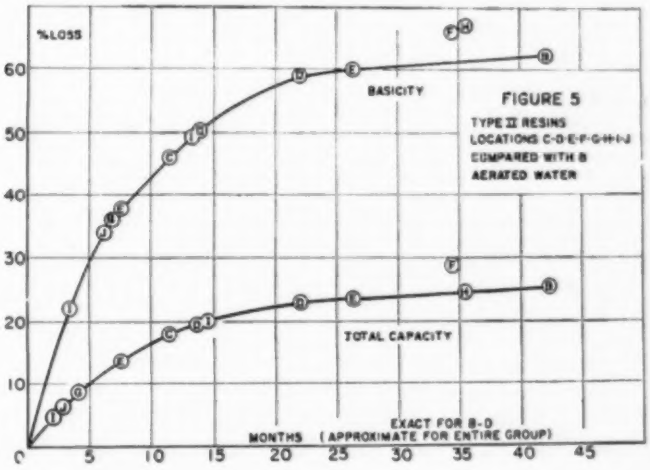

Fig. 5—Regenerating frequency, Table I, seemed to have little bearing on the basicity losses of all type II resins, right

These curves served as a basis for comparison with other locations where a lesser sampling frequency was necessary. As pointed out, the data from locations A and B represented results under widely varied conditions of operation of the same anion exchange resin, therefore making it possible to determine reasons for variation in the progress of degradation experienced. By again referring to Figs. 1 and 2, it was quite obvious that laboratory studies indicated little or no difference in resin stability in water or in a 4 per cent sodium hydroxide solution at temperatures below 125 F. In applying this information to the difference between the resin condition at location A (illustrated as Fig. 3) and at location B (illustrated as Fig. 4), it seemed highly improbable that the regeneration frequency was responsible for the greater basicity loss evidenced at B. This strongly indicated some other factor, such as oxidation, was contributing to the rate and extent of quaternary degradation. All of these studies have been confined to resins operating in the hydroxide form since anion exchangers in the chloride, sulfate and bicarbonate form exhibit more favorable stability characteristics.

In Table I representative samples of the contemporary highly basic anion exchange resins in use under highly varied conditions have been grouped into two classifications, namely regeneration frequency approximating location A and regeneration frequency approximating location B. All of the waters passing through these resins, excepting at location A, contained oxygen.

If resin degradation is to be considered a function of both the regenerating frequency and the oxidation potential of the solution being treated, different patterns of degradation should develop as one, or the other of these conditions vary. At location A, the effect of all but traces of dissolved oxygen in the water passing through the anion exchange resin was eliminated. There is a rate of basicity loss and total capacity loss over a period of operating time established for this condition. A distinctly different rate of loss, as you might expect, is established for condition B.

Type II anion exchange resins from all other locations studied, which are listed as C through J in Table I, have maintained rates of basicity loss and total capacity loss closely related to B throughout the period of operating time covered. Materials at C and H have been replaced with type I resin.

In Fig. 5 the total capacity and basicity losses experienced at locations C through J are compared with B. The type I resins exhibit greater stability than the type II materials, at least when comparison is made on the basis of early use.

In Fig. 1 the basicity loss of type I resins is compared with that of type II materials in accelerated 200 F tests.

In Fig. 6 we plotted the data obtained from the type I resin which is also in use at location A where it operates on deaerated water. The locations under our observation using type I resin have not been sufficient in number to arrive at a conclusion as to the effect of dissolved oxygen on stability with long term use. Resin which has been operating $3^1/_2$ years on aerated water shows stability characteristics well in line with location A and these data are plotted also on Fig. 6.

A paper presented by Morrison (7) at the 14th Annual Water Conference contained data on both type I and type II resins which we assume were not operating on deaerated water. While Morrison's paper dealt primarily with problems of organic matter, type I resins cited in his paper show an appreciably greater rate of basicity loss than evidenced by our Fig. 6.

Effect of Losses

In the foregoing, an analytical study of the condition of several highly basic anion exchange resins has been described. To translate this information to terms of immediate value to the operator, it is necessary to measure the effect of these changes on the actual performance of the resin. *Before getting into this, it is important that the basic difference between the two types of highly basic anion exchangers and the effect of these differences on their operating usefulness as well as their economy of operation must be thoroughly understood.*

While type I and type II highly basic anion exchangers are the topic of discussion, it is necessary to include for comparative purposes a third product, the weakly basic anion exchanger of the styrene base type. Types I and II, highly basic anion exchangers, have 90 per cent or greater of their total capacity in the form of quaternary or salt-splitting capacity. The weakly basic resins do not contain quaternary groups although they may exhibit a slight amount of salt-splitting capacity. The total capacity of the weakly basic anion exchangers is roughly 1.75 times that of the type I or type II highly basic resins. The cost is approximately the same.

TABLE II—EFFECT OF LOSSES ON OPERATING CAPACITY

Test Water	Laboratory Studies 1	Laboratory Studies 2
Silica	20 ppm–10%	49 ppm–49%
Chloride	180 ppm–90%	51 ppm–51%
Total Anions	200 ppm	100 ppm

1–Regeneration 3.5 lb NaOH/cu ft at 4 per cent NaOH at 95 F.
2–Regeneration 5.0 lb NaOH/cu ft at 4 per cent NaOH at 95 F.

	Type II New Resin	Type II Location A	Type II Location B	Type I New Resin	Type I Used Resin
Test Water 1					
Capacity–kgr/cu ft To 1.0 ppm silica rise	15.3	12.8	11.3	9.5	8.0
Silica leakage	0.09	0.12	0.10	0.02	0.02
Test Water 2					
Capacity–kgr/cu ft To 1.0 ppm silica rise	17.5	12.9	12.3	13.8*	10.8*
Silica leakage	0.40	0.30	0.29	0.03*	0.03*

*–Regeneration 5.0 lb NaOH/cu ft at 4 per cent NaOH at 120 F.

The weakly basic anion exchanger is used primarily for removal of strong acids and exhibits only a small capacity for removal of weak acids, carbonic and silicic. Either type I or type II resins can be used where removal of weak acids in combination with strong acids is desired. However, if a type II resin is used for removal of weak acids only, or when deionizing a water containing principally weak acids, any loss in salt-splitting capacity will reflect an appreciable loss in operating capacity. As the mineral acids content of the water passing through the type II anion exchanger increases, the effect of basicity loss on operating capacity is felt to a lesser degree.

If a type I resin is used when deionizing a high mineral acids water, the operating economy will be poor, especially if chloride and nitrates are present in the water supply. The operating economy is a function of the regenerating efficiency which is measured by the rate at which each of the anions removed from the water during the exchange process is eluted from the resin during the regeneration.

When removing strong acids, the weakly basic resins are the most efficiently regenerated, the regeneration approaching that of a neutralization reaction. The type II resins are most economically used on water containing a high percentage of strong acids to weak acids and having a relatively low silica content. The type I resins are better adapted to waters containing a high percentage of weak acids. *To gain the value in the data which will follow, it is pertinent to realize that as the type II resin loses basicity, it assumes some of the operating characteristics of the weakly basic anion exchanger.*

Column studies have been conducted in the laboratory with new and used anion exchangers under like operating conditions. These studies show clearly how the reduction of salt-splitting capacity influences the operating capacity of the resin. Certain of these data which typify operation are contained in Table II. The used resins are those which have been in operation for 2 to 3 years, and previously discussed as location A and location B. It should be noted that while the operating capacity is lower with the used resins, the silica leakage is practically unchanged with Test Water 1 and is actually lower with Test Water 2. This decrease in silica leakage is explained by the fact that there is less silica to be removed from the resin during regeneration when the operating capacity is lower. In other words, the regenerant dosage is higher on a pound per 1000 gal basis with the used resins. These data illustrate the relative effectiveness of the new and used type I and type II anion exchangers when deionizing waters containing various percentages of silica.

Other Observations

As the type II highly basic anion exchangers undergo the changes which have been discussed, other changes in their operating characteristics occur aside from a drop in operating capacity. The rinse water requirement, for instance, increases, especially when producing deionized water having low conductance values. The rinse water requirement of type II anion exchangers with use can be roughly correlated with the percentage of quaternary capacity contained in the resin. In Fig. 7 the rinse volumes required in laboratory investigation of new type II resins, used type II resins, and also resins of the styrene base weakly basic anion exchanger type are plotted.

Any appreciable cation leakage occurring during actual operation of a deionizing unit will cover up these changes in rinse requirement to a considerable degree since low values of conductivity would not normally be

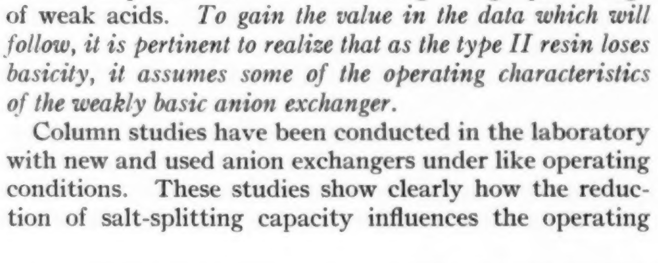

Fig. 6—Stability characteristics of the type I resins showed up much better in comparison with type II, Fig. 5, under aerated or deaerated waters

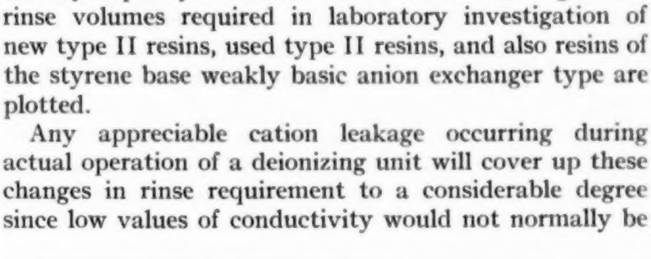

Fig. 7—Rinse water needs for type II resins increase as the basicity lowers and as the weakly basic groups form within the resin

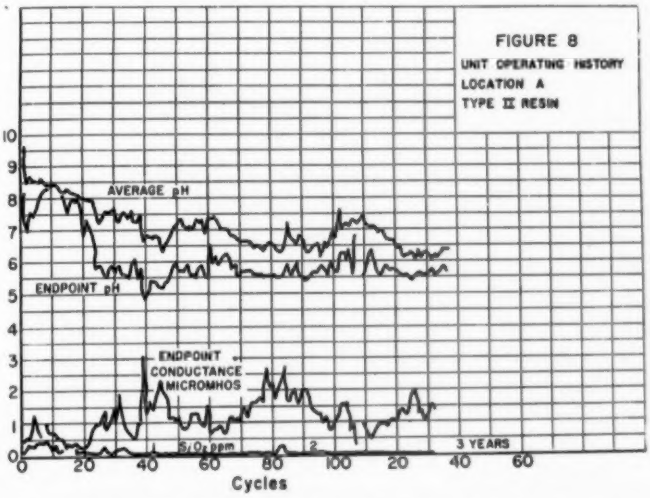

Fig. 8—Low pH value of deionized effluent has been experienced at some installations with type II resin. Author believes organic matter leaks may be the cause

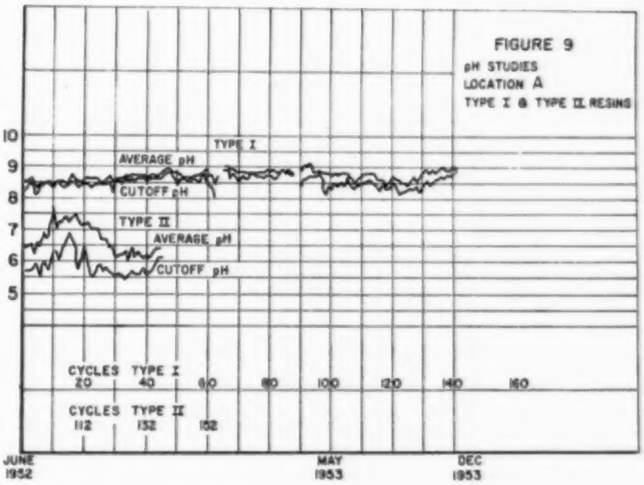

Fig. 9—Unit operating history where type I resin was employed showed a more stable pH for deionized effluent than with type II which indicates less leaks

obtained regardless of the amount of rinse water applied. The physical design of equipment housing the anion exchangers may also cause leakages which originate as regenerant dilution which will also camouflage the pictured change.

A second decided operating characteristic change occurs in the swelling and shrinking behavior of the highly basic anion exchangers as a reduction in salt-splitting capacity takes place. Type II resins containing 90 per cent or greater basicity of total capacity swell between 15 and 20 per cent upon conversion from Cl to OH forms. As the basicity lowers, the swelling lowers with values as low as 2 per cent being observed with used materials.

The change in rinse characteristics, the reduction in swelling when converting from the salt to the hydroxide form, and the greater ease of elution of chlorides and sulfates from the anion exchanger which has undergone a reduction in salt-splitting capacity all add up to verify the fact that the resin is assuming the characteristics of the weakly basic styrene type anion exchangers.

Poor Quality and Low Capacity Causes

Up to now there have not been many data available on organic matter in water and its effect on the strong base anion exchangers. It has been stated that certain organic bodies present in water being deionized are exchanged irreversibly (7) with exchange capacity to the conductivity break being reduced sharply. A condition of poor water quality has been particularly evident with the mixed bed unit with the problem not too generally recognized in the past with the 2-bed or other type units. This is no doubt due to the fact that the mixed bed unit is capable of producing an effluent so low in conductivity (or high in resistivity) that trace constituents escaping the unit have a significant effect on the conductance and pH value, at least in the range where it is measured.

Where the conventional 2-bed deionizer is used the production of water in the 0.5–2.0 micromho range is not generally necessary. But water of this quality or better has to be produced so that the influence of trace amounts of weak acids on the water quality can be readily recognized. For this reason a cyclic history of three years' operation of a 2-bed deionizer utilizing the type II anion exchanger is plotted in Fig. 8. Cation leakage at this plant is so low that sodium is not normally detected in the cation effluent water.

By studying Fig. 8 it is clearly evident that the average and end point pH values during each cycle of operation have dropped with the passage of operating time. This pH change has occurred simultaneously with the drop in basicity percentage of total capacity of the type II resin in use.

In Fig. 9 the average and end point pH values of a 60-in. bed of type I resin are plotted covering $1^1/_2$ years of cyclic operation. Cycles 93 through 132 from Fig. 8 are plotted on Fig. 9 also. This represents operation of both type I and type II resins over the same period of time and on the same influent water. The constituent causing the pH drop in the type II resin effluent in this instance, regardless of its composition, is not passing through the type I resin. It has been very difficult to determine exactly the cause of this. However, it has been quite clearly established that some organic matter is being removed by the type I resin that is not being removed by the type II material.

To gain a better understanding of the situation we took samples. The type I resin that has been operated $2^1/_2$ years was examined in column operation and exchange capacity found to be somewhat lower than expected for the known condition of the resin. Treatment in the column with a 4 per cent sodium chloride solution applied as a regenerant in large quantities caused much color to be eluted from the resin. During normal regeneration with sodium hydroxide no such color throw was evidenced. Then the exchange capacity with subsequent column operation was improved to a point in keeping with the known condition of the resin Treatment of the type II resin caused some color to be discharged.

The column method of evaluating resins differs from that used to obtain total capacity and basicity values. Treatment with sodium chloride or, as frequently suggested, with sodium hypochlorite has never improved on the total capacity or basicity values obtained on either type resin. Two distinctly different circumstances exist, namely capacity loss caused by degradation of the resin with use and capacity loss beyond that attributable

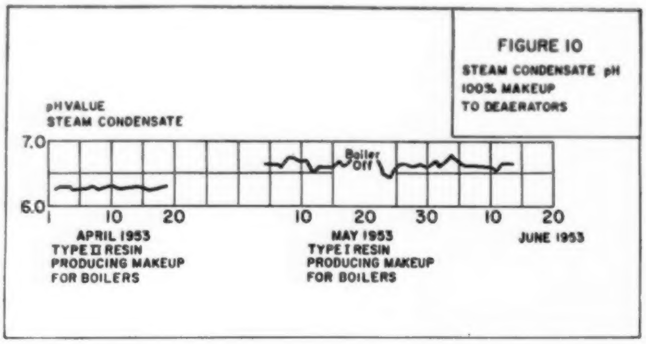

Fig. 10—Daily average steam condensate pH has been plotted for several days; first with a type II resin producing the makeup water and then again with a type I resin producing the makeup water. The low pH with the type II seems to imply carbon dioxide is the major cause

to degradation caused by fouling of the resin. In certain cases, the latter loss may be restored.

For nearly three years time all of the water for 1250-psig steam generation purposes at location A was deionized using the type II resin. For a period of time the deionizing operation was carried out with type I resin only supplying all of the make-up water, which is 100 per cent, to the deaerating heater. In Fig. 10 the daily average steam condensate pH for several days operation with type II resin is plotted and then again for a period of operation immediately following when the make-up water was produced by type I resin. The steam condensate pH during type II resin operation averages 6.3 pH. During the period covered by type I resin operation the steam condensate pH value was 6.6–6.7 pH. This bit of information seems to imply that the low pH effluent with the type II resin is attributable to carbon dioxide. This has not been confirmed, however. But all these are fine points. When working with waters as pure as these are it must be remembered that all measurements of contaminants are considered to be very small numbers.

We believe that a great deal of the difficulty of low anion exchange capacity following relatively short operating periods is due primarily to the application of the wrong type of resin to the particular water supply. Resins have been examined which were supposedly fouled with organic matter. Short operating cycles were being experienced. Yet further investigation of the problem in many instances revealed that the short capacity was due to the basicity loss of the type II resin which had been applied for deionizing a water containing very high percentages of carbon dioxide.

For a considerable period of time the resin used in mixed bed and 2-bed installations was predominately the type II resin. With mixed bed applications, the weak acids percentage of total anions may be quite high since no decarbonator is used. The loss of basicity experienced with type II resins will effect a very marked reduction in operating capacity when weak acids content of the water being deionized is high. It has been established in Figs. 3, 4 and 5 that the loss of basicity is immediately evident with the type II resins while this loss progresses at a significantly slower rate with the type I resins as illustrated by Fig. 6.

The maximum operating capacity and economy obtainable for a given condition results if the application of anion exchange resin is correctly suited to the water supply as outlined in Table III. If this procedure of selecting resins is adhered to, a minimum of operating difficulty will be experienced.

Acknowledgment

Preparation of a paper of this type requires the real cooperation of plant operators and the laboratory in the accumulation of volumes of information which may be coordinated to give a picture of the general problem. We wish to acknowledge the assistance of the members of the Nalco Ion Exchange Division Laboratory and all of those who have so generously supplied samples of ion exchange resins and operative data over extended periods.

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DISCUSSION:

This paper appears to be a valuable contribution to the knowledge of strong base ion exchange resins and will be given a great deal of careful study. There is one item though, that needs special emphasis. This has to do with the possible effect of dissolved oxygen on type I resins. There is no evidence presented in the above paper that aerated water results in any greater deterioration of type I resin than occurs with deaerated water.

Fig. 7 shows rinse requirement in terms of gallons required per cubic foot of resin versus per cent basicity of total capacity. As the basicity falls off in use, the rinse requirement goes up. This is all well and good but evidence from the field shows that used strong base anion exchange resin hangs on to caustic soda with considerable tenacity and that quite prolonged rinses are required before all traces of caustic soda leach are gone.

H. B. Gustafson, Infilco Co., Tucson, Arizona

Mr. Wirth has suggested that the presence of oxygen in the water tends to accelerate the deterioration. This is based on comparison of the results at installations A and B, Table I. Actually, although the volume of water treated per cubic foot of anion exchanger is approximately the same at both installations, installation B has had a few thousand regenerations whereas installation A has only had a few hundred. On the basis of this limited test data, it is difficult to arrive at definite conclusions and accept the idea that the greater deterioration of resin at installation B than at A is caused only by oxygen.

Although Mr. Wirth discusses the effect of organic matter only incidentally, we have found that organic matter may give difficulty with operation. We agree, though, with him that effect of organic matter is superimposed on effect of chemical changes in resin structure.

M. E. Gilwood, Permutit Co., New York, N. Y.

*Coal Burning Gas Turbine Progress in 1953**

By JOHN I. YELLOTT and PETER R. BROADLEY

Director of Research and Assistant Director of Research, Locomotive Development Committee, Bituminous Coal Research, Inc.

The Locomotive Development Committee has now accumulated 2182 hours of operating experience with full-scale direct-fired coal-burning gas turbines. Five 250-hour tests have been run with a Houdry process turbine lent by the U. S. Bureau of Mines. 932 hours have been run with L.D.C.'s 4250-hp Allis-Chalmers locomotive-type power plant. 750 of these hours were run at high load with coal as the only fuel. Following the evaluation of the results of the 750-hour test, the American Locomotive Co. advised the Committee that Alco wished to join with L.D.C. in continuing the project.

Coal Supply Study

The original goal of the L.D.C. program was the development of a self-contained locomotive power plant which could process and burn bituminous coal of any kind, size and moisture content. Operating experience has shown that little if any restriction need be placed on the kind of coal, but a more realistic requirement must be established for size consist and moisture content. The coal must be free-flowing when it reaches the locomotive bunker, without foreign matter which can interrupt the fuel supply. Somewhere between the coal seam and the gas turbine combustor, the coal must be pulverized to a fineness of at least 95 per cent minus 100 mesh.

Through the operation of a Sub-Committee on Coal Supply, L.D.C. is reviewing the entire problem of supplying suitable coal for gas turbine locomotives. Cost estimates are being prepared to permit economic evaluations to be made of the various systems which have been proposed for supplying "gas turbine coal."

Revision of the Dunkirk Coal Supply System

The pulverized coal required during the next turbine test program will be supplied by the equipment used during the 750-hour test, rearranged to separate the stoker and pulverizer from direct connection with the turbine feed tank. As Fig. 1 shows, the coal from the pulverizer is delivered through a cyclone separator into a large storage tank. The separator is vented through a dust collector, with the fines returned to the storage tank by a screw conveyor. A pneumatic conveyor transfers the pulverized coal to the turbine feed tank.

The L.D.C. rotary coal pump, Fig. 2, feeds the pulverized fuel from the scale-mounted turbine feed tank into the conveying air line which carries it to the twin combustors. Flexible connections enable the feed tank to be weighed and the coal consumption rate to be determined accurately. A variable speed electric transmission drives the coal pump and serves as the turbine throttle by regulating the speed of the pump rotor.

Ash Separator Development

During the first 178 hours of operation of the 4250-hp turbine, no appreciable damage was done to the blading by erosion. During this period, the ash separator functioned continuously at top efficiency and the ash particles entering the turbine were virtually all smaller than 20 microns in diameter. Early in the 750-hour test, a leak occurred within the separator and serious erosion took place. When the leak was repaired and high load operation was resumed, separator performance was found to be quite erratic and consistent operation at high efficiency could not be maintained. The reason for this inconsistency did not become apparent until, at the conclusion of the test, the discharge manifolds were cut apart and obstructions found.

When the L.D.C.-Alco program was being formulated, it was realized that the separator was the key to successful operation of the direct-fired coal-burning gas turbine. The Development Laboratory was accordingly given the assignment of improving the Dunlab separator tube and designing an ash blowdown system which could not be obstructed. A new Multitube separator was designed in which the individual tubes acted as their own pressure vessels, thus eliminating the large pressure shell which was formerly used to contain the separator tube battery.

The separator test stand was put to work on a two-shift basis and, starting with the original Mark I Dunlab tube, hundreds of tests were run at full turbine temperature, 1300 F. All of the dimensions of the tube were varied systematically, and it was found that the original dimensions were very close to the optimum. A major improvement was made when the tangential blowdown line of the Mark I tube was replaced by the annular blowdown, Fig. 3. In this arrangement, an annulus surrounds the bottom of the tube, with a $^1/_4$-in. gap between the cylindrical barrel and the flat bottom of the tube. A radial blowdown line, $^3/_4$ in. in diameter, carries the separated ash away from the annulus. Particles larger in diameter than $^1/_4$ in. cannot pass under the lip leading to the annulus; instead, they continue to swirl around in the tube until they are reduced by attrition to a size small enough to pass under the lip and out through the blowdown line.

Need for Adequate Air Flow

The most important factor in the efficient operation of the Dunlab separator tube is the maintaining of an adequate

* Excerpts from a report presented on March 23 before the First Techno-Sales Conference of Bituminous Coal Research Inc., Columbus, Ohio.

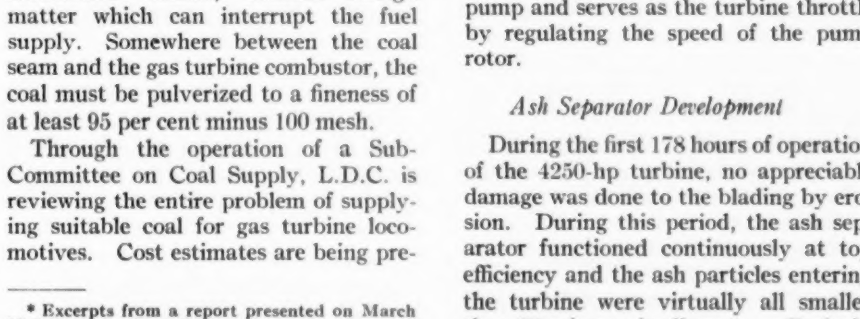


Fig. 1.—Gas Turbine test plant at Dunkirk, N. Y., as revised for 1954

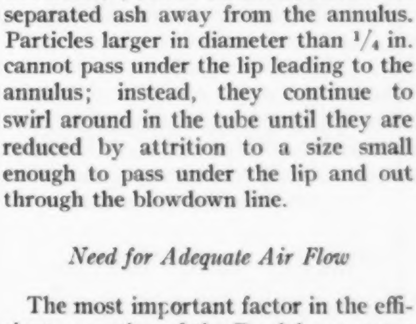


Fig. 2—Components of rotary coal pump

air flow through the blowdown line. As long as this flow remains above 12 cfm, the tube will operate at maximum efficiency. If the blowdown flow falls below 10 cfm, some of the separated dust will be re-entrained and carried out through the cleaned air discharge. The loss in efficiency which occurred with the Mark I tubes during the 750-hour test was apparently caused by gradual reduction of the blowdown flow below 10 cfm required to maintain maximum efficiency.

In order to prevent a recurrence of this situation, a method has been developed for continuously measuring the blowdown flow without interfering with the operation of the tube. The annulus casting, Fig. 4, is provided with one pressure tap in the elliptical section where the blowdown line leaves the annulus; a second tap is located at the smaller cylindrical section just ahead of the outlet flange. The pressure drop between these two taps is an accurate indication of the blowdown air flow rate.

The ash separator used during the 750-hour test consisted of a battery of 26 Mark I Dunlab tubes mounted within a large Inconel X pressure shell. The blowdown lines were connected to two manifolds which were brought out through the pressure shell. With this design, it was impossible to check on the performance of individual tubes during operation and obstructions in the blowdown lines could be removed only by shutting down the plant and opening up the separator shell. To eliminate these difficulties and to take full advantage of the Mark III Dunlab tube, two new Multitube separators have been built in which the individual tubes are used as pressure-sustaining elements, and the large expensive shell has been eliminated.

Since the total air flow to the turbine is almost 40,000 cfm, and each Dunlab tube can handle 1500 cfm, the new

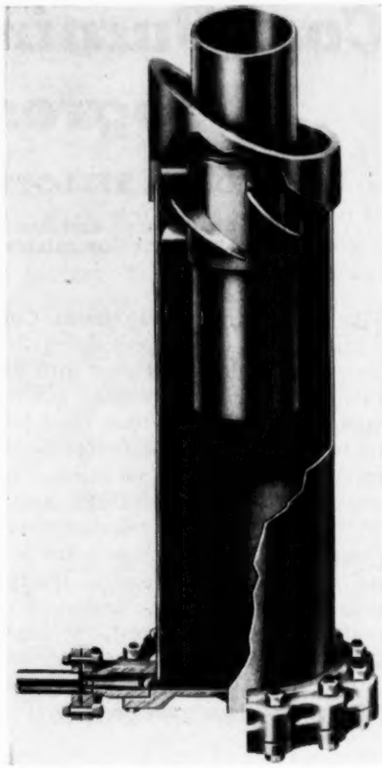


Fig. 3—Mark III Dunlab fly ash separator tube annular blowdown

Multitube separator uses two 13-tube batteries in parallel, Fig. 4. The body of each separator consists of a 28-in. diameter horizontal cylinder which is divided by a slope sheet into a lower dusty-gas inlet and upper cleaned-gas outlet chamber. The ash-laden hot gas from the combustion chamber enters the lower part of the separator through a tee, and finds that the only exit is through the Dunlab tubes. Vanes at the entrance of each tube cause the air and ash to spin rapidly and the resulting centrifugal force throws the ash toward the tube wall. Most of the ash particles enter the annulus and flow out with the blowdown stream, while the cleaned

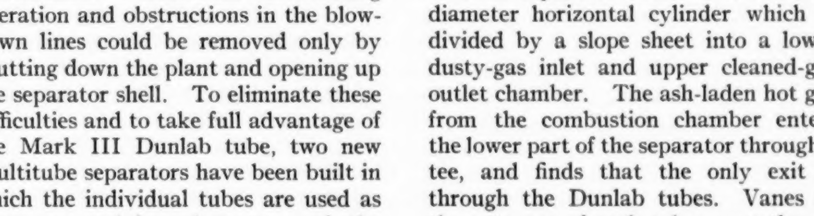


Fig. 4—Multitube fly ash separator with detail of blowdown connection

air and the ultra-fine ash particles spin up through the discharge tube and proceed to the turbine.

The blowdown lines are connected into manifolds as shown in Fig. 4. In order to equalize the blowdown flows, each line is provided with a bushing which is inserted in the outlet flange. These bushings are graduated in inside diameter, with the larger bushings inserted in the tubes which are farthest away from the separator inlet. The manifolds are connected to the ash concentrators which divert the ash and a portion of the blowdown air to the ash disposal system, while the remainder of the air is discharged through a nozzle to the stack.

Instrumentation

Continuous determination of separator performance will be of the utmost importance during the coming test. For this reason, ash samplers have been installed at the entrance of each separator battery, in addition to the samplers at the turbine inlets. Comparison of the weights of ash caught at these points during a given time interval will enable the operators to calculate the actual separator efficiency for that interval. Since there is a close correlation between the amount of ash entering the turbine and the particle size distribution, samples of the ash from the turbine inlets will be examined frequently under a microscope, to check the percentage of plus 10 and plus 20 micron particles.

Two new methods of detecting erosive ash will be utilized in the next test program. Early in 1953, a project was established at the Armour Research Foundation to develop better and faster methods of determining the erosiveness of the ash particles entering the turbine. Two methods were selected, the first using the change in electrical resistance of a rod exposed to erosion in the turbine inlet stream; the second method uses radioactive techniques.

In the radioactive method, samples of the dust-laden air from the two turbine inlets are directed at high velocity against small irradiated targets of S-4 590, the alloy used in the cylinder blading. The air streams are then led through slowly moving filter paper tapes, where the ash and removed metal fragments are caught. Scintillation counters scan the moving tapes continuously and indicate the radioactivity of the observed portion of the tape in terms of "counts per minute."

If the ash impinged on the targets is non-erosive, the count rate will be quite low, corresponding to the background at the test location. If the ash is coarse and erosive, the count rate will go up in direct proportion to the amount of irradiated blade material "seen" each minute by the scintillation counter. A continuous record of the count rate will be kept and an alarm will be sounded if it exceeds a predetermined value. The great advantage of the radioactive method is its speed; less than one minute is needed to detect the presence of erosive ash.

Italian Purchases and Production of Coal

GIOVANNI COPPA-ZUCCARI

Rome, Italy

ITALY has considerably increased her purchases of coal from the countries of the European Coal and Steel Community. In the first ten months of 1953 the imports of this fuel from Belgium, France and Germany amounted to 3,966,159 metric tons, as against 2,997,665 mt in the corresponding period of 1952. At the same time the imports from England increased from 787,392 to 1,445,642 mt, while those from the United States decreased from 2,665,704 to 1,220,920 mt.

These significant variations are due to the increasing importance taken by the Community market with regard to the Italian industrial needs. If we take into account the fact that the prices of the American coal are considerably less than for the corresponding European product and that the consumers generally prefer the United States as source of supply, we must conclude that the above-mentioned trend in the Italian coal supply represents a substantial contribution given by Italy to the consolidation and efficiency of the European Coal and Steel Community.

At its last meeting the Italian Coal Committee examined the situation of the supplies and the program for the first three months of the present year. This situation is, on the whole, satisfactory; the shipments for the first eleven months of the last year amounted to 8,058,071 metric tons, a quantity 5,000 mt in excess of that registered in the corresponding period of 1952. From January 10 to November 30, 1953, Italy imported the following quantities of coal: 3,206,729 mt (as against 2,718,203 in the same period of the preceding year) from West Germany; 1,594,276 mt (as against 933,274) from Great Britain; 1,394,214 mt (as against 2,812,109) from the United States; 776,637 mt (as against 494,380) from Belgium; 533,985 mt (as against 629,210) from Poland; 323,807 mt (as against 147,075) from France; 162,887 mt (as against 110,872) from South Africa; 53,966 mt (as against 43,063) from Yugoslavia; 35,260 mt (as against 119,518) from Russia; 3310 mt (as against 13,322) from Morocco.

The output from the Sulcis mines decreased in November by about 900 mt owing to the reduced daily productivity of labor; the stocks in Porto S. Antioco decreased by 6,000 mt.

The Coal Committee approved the program for the first three months of the current year. The total amounts to 2,594,000 mt, 294,000 of which are allowed to coke works, 425,000 to gas works, 120,000 to thermoelectric power stations, 130,000 to the iron and steel industry, 500,000 to other industries, 400,000 to railways and 70,000 to domestic utilization. Out of this total 220,000 mt can be supplied by the national sources, while the remainder is to be purchased abroad. The largest quantities will come from the countries of the European Community (1,649,000 mt), but this figure is less than that in the preceding three-month period.

The Committee examined with particular care the situation of imports from USA. A cause for concern is that availability on the Procurement Authorizations is presently exhausted. The committee therefore approved the importation of 300,000 metric tons of American coal to be paid in free dollars; this decision was taken in the expectation of new measures apt to facilitate the imports from the United States of America.

Business Notes

Significant advances in the design of steam turbine-generators occurred in 1953 according to the latest report of Glenn B. Warren, vice president of **General Electric Co.** The average size of large turbine-generators leaving the G-E shops in 1954 will be about 110,000 kw. Turbine-generators rated at 217,000 kw, cross compounded, are scheduled for 1954 operation.

Three Pennsylvania schools will be recipients of the annual $12,000 **Dravo Corp.** scholarship fund. These schools are Carnegie Institute of Technology, Lehigh University, the University of Pittsburgh. Both Lehigh and Carnegie Tech. will grant scholarships in engineering, whereas Pittsburgh's will be in business.

John F. O'Connell, vice president, **Bechtel Corp.,** was elected president of the National Constructors' Association, an organization composed of national firms engaged in engineering and construction of power and chemical plants as well as steel mills and refineries. J. H. Sharpe, **Arthur G. McKee & Co.,** became the Association's vice president.

A new mechanical development laboratory devoted to the refinement and adaptation of present products and processes, as well as promotion of new products, is planned for the Metal Products Div. of **Koppers Co., Inc.** The laboratory will be erected at the South Baltimore, Md., plant of Koppers and will house fifty engineers and technicians on its staff.

American Gas and Electric Service Corp. announced the promotion of ten key engineering personnel: V. M. Marquis, formerly vice president of system operations and planning, to vice president and assistant to the president; S. N. Fiala, formerly mechanical engineer, to chief engineer; F. A. Lane, formerly electrical engineer, to deputy chief engineer; H. P. St. Clair, formerly system planning engineer, now planning and operating engineer manager; T. T. Frankenberg, formerly assistant mechanical engineer, to mechanical engineer; F. M. Porter, formerly electrical equipment section head, to electrical engineer; J. H. Kinghorn, formerly assistant electrical engineer, to deputy electrical engineer; G. W. Bice, formerly steam generation section head, to assistant mechanical engineer; H. F. Hoebel, formerly senior engineer, electrical engineering dept., to assistant electrical engineer; J. E. Geue, formerly plant consultant, to operating manager, production.

A downtown Engineering Center, to cost $1,378,000, has been announced by the **Cleveland Engineering Society** as the high point of its 75th Anniversary celebration. The Society, with a present membership of 2000, anticipates an enrollment of 4000 so that the new headquarters will be very definitely needed in the not too distant future.

Panellit, Inc., has begun construction of its new 82,000-sq ft, single-story plant at Skokie, Ill., with plans calling for an eventual 150,000 sq ft. Included in the move to the new plant will be two Panellit subsidiaries, the Panalarm Products, Inc., and Panascon, Inc.

A Heat and Mechanics Section has been formed in the **Stanford Research Institute** according to R. A. Krause, general manager of research divisions, and it will be headed by J. Kenneth Salisbury, formerly manager of the thermal power systems division of General Electric Co.

The six plants of the McLain Fire Brick Co., along with the entire business and rights of the company, will be acquired by the **H. K. Porter Co.** soon, according to a release by T. M. Evans, president of Porter. The new enterprise will operate as the McLain Fire Brick Co., division of H. K. Porter Co., Inc.

REVIEW OF NEW BOOKS

Any of the books here reviewed may be secured through Combustion Publishing Company, Inc., 200 Madison Ave., N.Y.

Construction Methods and Machinery

By F. H. Kellogg

One phase of engineering that has remained more of an art than a science is construction. In this book the author, who is the dean of Engineering at the University of Mississippi, applies reason and logic to the formerly almost empirical practice of construction without losing sight of strictly practical methods. He attempts to bridge the gap between the predominantly deductive reasoning of the engineering school and the inductive reasoning so common in construction practice.

The book has three major divisions: organization and planning, machinery, and construction methods. The first part takes up organization and planning, methods of control, and equipment economics. Under machinery the author considers the various forms of power services required on construction jobs, transportation methods, techniques for hoisting and conveying, and considerations in selecting and operating pumping equipment. Topics discussed in the third part of the book are site preparation, earthworks and rock excavation, foundation treatment, aggregate and concrete preparation, and structural erection.

Much useful information for estimating is included in an appendix, in which there is also incorporated a bibliography containing 70 listings. Throughout the book a quantitative approach is used, including many examples which are worked out in some detail.

There are 415 pages in the book which sells for $10.

Elementary Fluid Mechanics

By John K. Vennard

In the Third Edition of this widely used text the author has followed the same approach used in earlier editions but has extended the coverage by about 10 per cent. Presentation of the subject begins with a discussion of fundamentals, physical properties of fluids and fluid statics. Fluid flow is introduced by a very brief chapter on broad concepts and principles intending to show the relationship between fluid mechanics and thermodynamics. Frictionless fluid flow is discussed for incompressible and compressible fluids, and the impulse-momentum principle is then developed. A semi-quantitative description of frictional processes and a chapter on similitude and dimensional analysis complete the presentation of primary tools and lead to applications to pipes, open channels, measuring devices and flow about immersed objects.

Each chapter includes bibliographical references from which the interested reader can obtain more detailed information. Throughout the text many principles are explained through the aid of illustrative problems, and at the ends of chapters a total of nearly 900 problems is included.

There are 401 pages in this textbook which sells for $5.50.

Dictionnaire Technique Anglais—Francais, Chauffage Industriel

By I. Dusnickis

This is a specialized English-French technical dictionary dealing primarily with terms used in steam power plants and industrial heat treatment. It should be useful for French readers who are concerned with drawings and technical correspondence in English. It is divided into six sections, of which the first provides common abbreviations and conversion tables and the second, terms relating to expressions appearing on drawings and in technical correspondence. Other parts are concerned with the terminology of steam generators, industrial furnaces, control and regulating apparatus, and chemicals and refractories, including water conditioning.

The paper-bound technical dictionary contains 144 pages and sells for $3.00.

Personals

Raymond V. Thayer, formerly field engineer out of the Cincinnati office of the Elliott Co., has been appointed district manager of the same office.

Karl J. Wagener, assistant chief engineer since 1946, has taken over the duties of chief engineer for the Baltimore & Ohio Railroad Co. in place of the recently retired **Alfred C. Clarke,** chief for the last thirteen years.

A. O. Jaeckel, formerly general manager of the Davis Engineering Corp., has been elected president of the concern and will continue as its general manager. **Frank F. Kunca,** formerly comptroller of the corporation, became its treasurer.

Leeds & Northrup Co. announced the promotion of two sales engineers, **Wilson D. Trueblood, Jr.,** formerly of Chicago, and **Willard H. Neu,** formerly of the Pittsburgh office, to district managerships. Trueblood takes over in Milwaukee and Neu in Cincinnati. **Edwin A. Yeo,** manager of Cincinnati for sixteen years, moves over to manage the Pittsburgh office.

Three new appointments were recently made at the Copes-Vulcan Div. of Continental Foundry & Machine Co. They were: **John A. Vanyo, Jr.,** to the post of assistant sales manager, **O. H. Keeling** to manager of combustion control engineering, and **R. L. Bruce** to senior contract engineer.

Howard W. Hudson has been appointed vice president of Panalarm Products, Inc.

Dr. Roger Adams, chemist and educator, has accepted appointment to the Board of Trustees of the Battelle Institute, where he joins the six-man self-perpetuating Board, whose chairman is **Dr. Zay Jeffries.**

Ramtite Co. recently added **George Shutak** to the sales engineering staff of their Cleveland-Youngstown office.

Two new assistant managers of engineering and the creation of three new departments have been announced by the Detroit Edison Co. The two new assistant managers of engineering are **Edward R. Moore,** former chief of the engineering dept., and **Harvey A. Wagner,** former assistant chief. Both of these men will report directly to **H. P. Seelye,** manager of engineering. Wagner will continue his assignment of coordinator of the company's nuclear power development dept., with the title of director of nuclear power development. The three new departments are: design engineering under **Edward L. Nugent,** as director; engineering coordination and services under **Simon Roth,** director; planning and project engineering under **W. Fred Wetmore,** as director.

W. H. Rowand, vice president of Babcock & Wilcox Co., has been awarded the Newcomen Medal for his contributions to steam progress at a recent meeting in Philadelphia.

Joseph Griscom, Jr., became manager of southern sales for the Benjamin F. Shaw Co. following his appointment at the company's recent annual meeting of the directors.

NEW CATALOGS AND BULLETINS

Any of these may be secured by writing Combustion Publishing Company, 200 Madison Avenue, New York 16, N. Y.

Electric Motors

Complete descriptions of new maintenance, performance and protective features of the company's 1 to 30 hp Tri-Clad "55" motors make up a new four-color catalog released by the General Electric Co. One, GEA-6013, covers drip-proof models in 16 pages; a second, GEA-6012, enclosed motors in 8 pages, and a third, GEA-6027, describes the new gear motors in 14 pages.

Combustion Control

A new boiler plant designed for high efficiency, easy future expansion and maximum fuel flexibility form the subject matter of an 8-page bulletin, R-9, recently announced by the Hays Corp. A signed article by the plant's chief power engineer describes the plant and the workings of its combustion control system.

Transmission Belts

Fully illustrated, 4-page bulletin describes the complete line of flat transmission belts put out by the Quaker Rubber Corp., Division of the H. K. Porter Co., Inc. The bulletin lists recommended uses, specifications, construction data, sizes and lengths.

Industrial Cork Products

Physical characteristics and uses for both natural cork and cork compositions along with government and SAE-ASTM equivalents of Dodge Cork Co.'s composition, plus sheet sizes and thicknesses, constitute the material in a newly available 4-page bulletin, S-4.

Liquid Level

A dozen different systems for measuring and controlling liquid level are featured in the 24-page Bulletin 1160 recently announced by the Industrial Div., Minneapolis-Honeywell Regulator Co. Brief general sections on measurement, transmission and control, and handling of difficult liquids are included. For quick comparison purposes a 2-page tabulation of the twelve different systems has been presented.

Pressure Gage

Seventeen specific sections covering such important subjects as quality gages, drawn case gages, Duragauges, special industrial application gages, barometers and gage accessories as well as gage engineering information comprise the 124-page Manning, Maxwell & Moore, Inc.'s Ashcroft Gauge Catalog. Supplemented by photographs, line drawings and dimensional drawings and also a number of selector tables, the catalog is made even more valuable with the aid of a contents and numerical index.

Sump Pumps

Construction details, head and capacity tables, and dimensions for a unit sump pump are the subject matter contained in the Johnston Pump Co.'s 8-page Bulletin 1029. The pump is a pre-engineered package unit made in a range of sizes that can be selected for existing conditions or new construction.

Synchronous Motors

Standard construction features of engine-type, low-speed synchronous motors in ratings of 100 hp and larger at speeds of 450 rpm and less make up the bulk of a 4-page Allis-Chalmers Mfg. Co. Bulletin, No. 05B8008. Stator, rotor and collector assembly features are described and illustrated with photos in the bulletin.

Pipe and Fin Coils

A revised second edition of the Rempe Co. 34-page engineering data book on pipe and fin coils is just off the press and is available without charge upon application on company letterhead. Vital information on design and calculation, heat transfer coefficients, factors for computing fin coil surfaces, plus recommended materials and effects of air velocities and Btu load limitations are included.

Chemical Feed

Several specially assembled chemical feed systems for various water treating requirements are outlined in the 4-page Bulletin T-1153 now available from the Philadelphia Pump and Machinery Co. These systems include single or partitioned tanks equipped with simplex or duplex pumps that can feed one or two chemicals in correct proportions for particular feeding problems. Accessory equipment takes in dissolving baskets, mixing and agitating equipment, floats, liquid seals, level alarms.

Flexible Coupling

To meet power transmission requirements for all classes of industrial applications, Lovejoy Flexible Coupling Co. have issued a 20-page catalog showing their own full line to fit all standard applications as well as those demanding extreme compactness, radial removal of machinery or independent rotation. Specifications and dimensions, cross-sectional drawings and descriptive material of the major designs are given.

Pipe Insulation

Lightweight, one-piece pipe insulation Mono-Kover, serves as the subject material for a 4-page Baldwin-Hill Co. bulletin picturing the insulation's ease of application as well as its properties such as thermal resistance, permanence, resiliency, and noncorrosive qualities. Added features are a chart for thermal efficiency, a suggested specification form and an insulation thickness selection table.

Blow-Off Valves

Full details of the Yarnall-Waring Co.'s Yarway seatless blow-off valves, and double-tightening blow-off valves for boilers up to 400 psi appear in the new 20-page Bulletin B-426. Additional information includes installation recommendations, construction details and prices.

Fuel Oil Heaters

The general subject of fuel oil heaters constitutes the material appearing in the 16-page Bulletin 1415 recently released by Griscom-Russell Co. The bulletin describes two units—the twin G-fin section with longitudinally-finned heat transfer elements and the Type B tubular heater. It explains the design details and features of both with illustrations of installations, specifications and tables. Selection tables have been provided for the twin G-fin section that will meet capacities from 50 to 31,000 lb per hr of 10 degree A.P.I. fuel and for the Type B heater to cover capacities ranging from 2 to 1000 gpm of Bunker C fuel oil; with oil to be heated from 100 to 225 F and for pressures from 25 to 250 psig in both tables.

Control Instruments

The complete line of the Wheelco Div., Barber Colman Co., makes up the subject matter of the 4-page bulletin F5633-1 recently released. The Wheelco electronic link which gives instantaneous control and recording action between the direct measuring unit and the control and recording system are discussed as well as the Flameotrol, heart of the manufacturer's system of combustion safeguards for burners.

New Equipment

Electric Motors

Completely redesigned line of motors to meet the new NEMA rating standards are now available at the Louis Allis Co., Milwaukee 7, Wis. The line, known as L.A., features all standard enclosures—open, drip-proof, totally-enclosed, fan-cooled and explosion-proof. They will be built to frame size 326 (40 hp at 3600 rpm), and this conformance to smaller external dimensions has been accomplished without sacrifice of motor service factors or a liberal design.

Signal Transmitter

Specially designed pneumatic signal transmitter permits adapting the Ring Balance meter of the Hagan Corp., Box 1346, Pittsburgh 30, Pa. to remote metering and control applications. The

transmitter is actuated by movement of the pen arm or indicator follower of the balance meter but does not introduce any perceptible load on the sensing element. Maximum signal pressure ranges are 15, 30 and 60 psi requiring a continuous supply of compressed air.

Reducing Valve

Pilot-operated, No. 933, steam reducing valve is claimed by its manufacturers, Klipfel Valves, Inc., Hamilton, Ohio, to meet the needs of most reducing valve installations and permit easy pressure adjustments. Downstream pressure is sensed by the diaphragm of the pilot valve. The pilot uses upstream pressure to open the main valve if downstream pressure is too low; if too high, it bleeds off the pressure allowing the main valve to close as required.

The valve is manufactured in sizes from $^3/_4$- to 6-in. with those below 2-in. having bronze bodies and the larger

sizes semi-steel bodies. Stainless steel disks and seats go in all valves 4-in. and smaller and bronze is used for inner valves and seats on the 5-in. and 6-in. designs.

Stainless trim can be provided on special order.

Instrument Valve

The new 6000-psi Hancock stainless steel instrument valve has been built especially for instrument panels and lines, gages, bypass and corrosive lines and orifice meters by Manning, Maxwell & Moore, Inc., 65 Grove St., Watertown 72, Mass. The units, available

in $^1/_4$-, $^3/_8$-, and $^1/_2$-in. sizes, are small, weigh only about $2^1/_4$ lb and permit pulling the packing gland up tight in close quarters or disassembling in the same confined space without appreciable difficulty.

Induction Motors

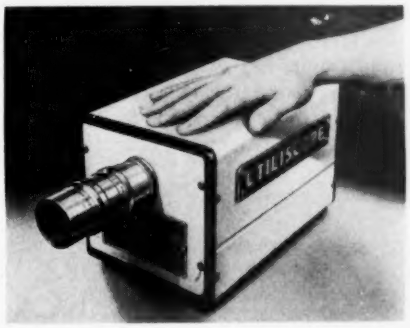
Complete new line of a-c squirrel cage induction motors, Type G, in frame sizes 182 and 184 have been announced by the Allis-Chalmers Mfg. Co., Milwaukee 1, Wis. to comply with the new NEMA standards and rerating. The new metals, insulation materials and heat transfer methods developed within very recent years are the background for the NEMA rerating. The new line means equal horsepower in a smaller package.

Cast-iron frames and end shields will

be used in the new line with rotors of pressure-cast aluminum, bearings of grease lubrication design, double-shielded ball bearings capable of re-lubrication without dismantling the motor and starter windings of heavy Formar-coated wire in semi-closed slots.

Wired Television

For industrial television installations where a smaller camera with high resolution and lower lighting levels are desirable, the Diamond Power Specialty Corp., Lancaster, Ohio, has developed the Model 300-BV which can be used instead of or be interchangeable with the standard Model 300-B Utiliscope



camera. The new model requires no trained operating personnel, is easily accessible for servicing and has the same basic features of operational stability and constructional ruggedness of the standard model.

Steam Regulator

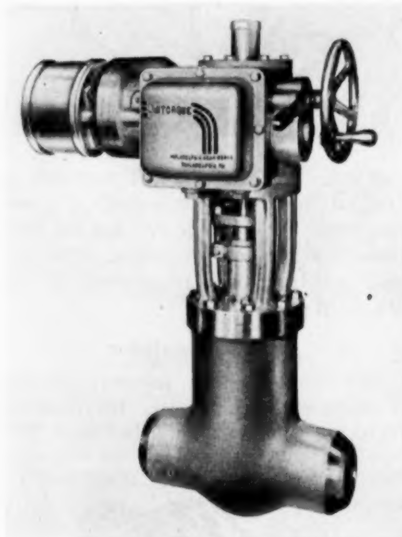
Self-closing safety feature prevents overheating damage to thermostatic regulator element on the new SFS

steam regulator put out by the Lawler

Automatic Controls, Inc., 453 N. Macquesten Parkway, Mount Vernon, N. Y. The new safety device, specially designed and constructed, automatically closes a direct-acting valve or opens a reverse-acting valve when thermostatic element is accidentally damaged or loses its charge. The regulator, in valve sizes from 1/2-in. through 2-in., has a bronze body, union ends, and a bellows bracket with a thermostatic element of the vapor tension type. It comes with six feet of armored capillary tubing, copper thermo bulb and tank bushing.

Automatic Valve Operator

An improved, reportedly more effective automatic valve operator, the SMA Limitorque, has been announced by its manufacturer, the Philadelphia Gear Works, Inc., Venango & "G" Sts., Philadelphia, Penna. The improved



and new features include: (1) greater torque, thrust and stem capacity, (2) easier de-clutching, (3) easier handwheel operations, (4) 2-piece stem nut design to permit changing unit from one valve to another, (5) improved switch design and electrical arrangement, (6) torque control for both directions of steam travel, or just in a single direction, if desired.

Conductivity Cell

Easily removed, readily mounted are advantages claimed for the new conductivity cell assembly of the Hagan Corp., Box 1346, Pittsburgh 30, Penna. It measures less than 10-in. long with flexible couplings employing rubber "O" rings and back-off nuts that make inspection and cleaning a relatively simple matter. The assembly can be furnished with cells having different constants. A bimetallic dial reading thermometer is supplied as a standard component and is said to give sufficiently accurate readings.